FOOD OR FAMINE

an account of the crop science program
supported by the
International Development Research Centre

IDRC-143e

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IDRC-143e

Food or famine : an account of the crop science program supported by the International Development Research Centre. Ottawa, Ont., IDRC, 1979. 79 p. : ill.

/IDRC publication/, /agricultural projects/, /Latin America/, /Africa/, /Asia/, /Middle East/, /Canada/ — /IDRC supported/, /agricultural research/, /agricultural training/, /sorghum/, /millet/, /triticale/, /cassava/, /leguminosae/, /oilseeds/, /root crops/, /cultivation systems/.

UDC: 63.001.1 ISBN: 0-88936-232-7

Microfiche edition available

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Foreword

It is, I believe, entirely justifiable that the Crop Science Program continues to represent the largest proportion of the Agriculture, Food and Nutrition Sciences Division's budget of the International Development Research Centre. Foods of plant origin, including cereals, food legumes, root crops, nuts, fruits, and vegetables, provide most of the nutrient requirements of all the people on earth. In addition to support for more than 100 crop science projects, the Agriculture, Food and Nutrition Sciences (AFNS) Division has provided a substantial input to the foundation and establishment of two international agricultural research centres, whose main responsibilities relate to previously neglected crops, and has encouraged and supported sizeable international research networks in semi-arid crops, cassava, triticale, and multiple cropping systems. The Division has made possible the cooperation of research scientists in several Canadian universities with their colleagues in international centres and developing country programs; the Canadians generally being engaged in fundamental studies related to applied research being undertaken overseas.

This publication brings together, in summary record, an account of what has been encouraged, attempted, and accomplished since the Associate Director for Crop Sciences began the program during 1971. It is one of a series written by IDRC staff members that describes the various activities of the AFNS Division. Earlier publications include, "AFNS: the First Five Years," "Trees for People," "Fish Farming," and "Removing Constraints to Small Farm Production: the Caqueza Project."

The essential brevity of this publication does not allow for more than a summary of the efforts and achievements of the scientists of many nations who have cooperated in the projects described. Those who are interested in obtaining further information about particular projects should write to the project leaders, whose names and addresses are included in the list of projects at the end of the book.

My colleagues and I will be pleased to provide additional information to anyone who cares to write to us at the following locations:

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Introduction

In 1974 the world experienced a serious food crisis. Among the factors contributing to this situation were adverse weather conditions over several years in the USSR, China, India, Southeast Asia, Australia, and Sahelian Africa, and the sudden large increase in oil prices in 1973, both of which caused worldwide inflationary pressures. Several hundred thousand deaths were caused, directly or indirectly, by famine in Sahelian Africa in spite of food aid programs that ran into millions of tonnes. Public attention was focused on the problem by the United Nations World Food Conference held in Rome the same year.

With better rains from 1975 to 1977, world food stocks increased toward more normal levels, and food prices declined steadily. Nevertheless, the International Food Policy Research Institute (IFPRI) estimated that about two-thirds of the total population of the developing countries (some 1.3 billion people) were underfed. The United Nations Organization has designated 38 of these countries as most seriously affected. These, the world's poorest countries, which have some of the highest population increase rates in the world, do not have sufficient foreign exchange to purchase the food they need. They are the most vulnerable to famine and to widespread undernourishment, and therefore need special help.

In many developing countries, there exist great disparities in wealth between a small elite section of the population and the desperately poor who inhabit the less fertile rural areas and the slums of major cities. Average figures for food available per capita disguise the true picture of many hungry and few replete.

In the 1950s and early 1960s, some believed that many of the food needs of the developing world could be supplied by food aid from the surplus grain of exporting countries such as Canada and the United States. It soon became apparent that these countries could not continue to feed a large proportion of the world's population, and that these large supplies of free or inexpensive grains often forced down grain prices in the recipient countries. This left farmers with little or no incentive to produce grain over and above their own needs. Also, it often became uneconomic for them to purchase inputs such as fertilizers or to invest in other means of increasing production. Therefore, local production frequently fell to very low levels and the countries affected became more and more dependent on foreign assistance.

India was one of the largest recipients of food aid in the 1950s. However, more recently, India has greatly increased its own grain yields through improved production methods. Much of the success in that country must be attributed to decisions taken by the Indian Government in the early 1960s to pay the farmers a fair price for their crops and to do everything possible to encourage increased food production. These policies, combined with the high-yielding varieties of wheat and rice that were introduced at about the same time with the rest of the agronomic practices necessary for growing them, brought the country to self-sufficiency in food.

India's example shows that although emergency food aid will still be needed for countries threatened by famine, and world food stocks must therefore be maintained sufficiently to provide insurance against a possible succession of bad years, the highest priority should be given to increasing food production within the developing countries.

The International Development Research Centre (IDRC) was set up mainly to foster research by nationals of the developing world directed at solving their own problems. The kinds of problems faced by the Centre's Agriculture, Food and Nutrition Sciences (AFNS) Division are those associated with the growing of crops and trees, the rearing of livestock and fish, and the handling and use of their products, especially for human food. When the Crop Science Program started in 1971, it was decided to give highest priority to support for research to increase the production and improve the quality of the indigenous food crops of developing countries.

Successful agricultural research workers need two basic qualifications: enthusiasm combined with dogged determination to solve the problem undertaken, and a thorough scientific training grafted onto a practical background and understanding of farming. IDRC first seeks to identify such outstanding scientists in their own national research institutions, then to support them in their research, augment their knowledge through further training, help them to obtain plant materials and up-to-date research findings, and link them with other workers by means of workshops and visits. These relationships are a characteristic of the program. However, for sustained agricultural progress to be made, the country in which the scientist is working must have the determination and capacity to build and support an effective infrastructure for agricultural research and development.

The ideal conditions for research are hardest to fulfill in countries that combine a low per capita gross national product with a low literacy rate, which means that the countries in greatest need present the greatest problems. These countries are often desperately short of qualified scientists and technicians. Therefore, perhaps the most important element of IDRC's contribution has been the provision of funds for the training of young scientists and technicians to work in the projects it supports. Training may consist of a few months in a local institution for a junior scientist or technician, or graduate training in Canada or some other appropriate country for a senior scientist. Whenever possible, arrangements are made for trainees to be registered for an appropriate higher degree while they are working on a project, so that their research is accepted for their degree and they only need to do their course work in the university in which they are registered. Because the Canadian International Development Agency (CIDA) has the responsibility for supporting undergraduate-level education, long-term educational support is usually only provided by IDRC at the graduate MSc or PhD level, and is designed specifically to work within one of the projects that IDRC is supporting.

Because it takes many years to train scientists, the institutions that IDRC supports sometimes ask for an expatriate research adviser to help with the project under the leadership of a national scientist. To establish the necessary links between scientists undertaking research on related problems throughout the world, IDRC has sought to establish networks of projects on the same crops in many countries where these crops are grown.

An important contribution to the success of many of these research networks has been made by the establishment of international agricultural research centres (IARCs). The first of these centres were the International Rice Research Institute (IRRI) in the Philippines, and the International Centre for the Improvement of Maize and Wheat (CIMMYT) in Mexico. These two centres produced the high-yielding varieties of rice and wheat (respectively) that made an important contribution to the relief of the food shortages of the 1960s and early 1970s. Several other centres have since been established, some of them with IDRC assistance, and have been given the world responsibility for the improvement of other important crops. By establishing close and friendly relationships with national crop improvement programs, these centres have been able to provide effective leadership to the networks involving crops and cropping systems for which they have responsibility. Particularly in the exchange of information and germ plasm, and in training, the international centres have been able to provide sufficient scientific support and encouragement to enable many of the national research programs to participate effectively in the networks.

The result has been the gradual development of a three-way partnership with IDRC and other donors providing funds to support research in the national research programs and the IARCs supplying scientific coordination. It has proven to be an effective way of accelerating food crop research in the developing world.

IDRC is supporting networks in five main areas of crop sciences: sorghum and millets; triticale; food legumes and oilseeds; root crops; and cropping systems.

Sorghum and millets are among the world's most widely grown cereals. They provide the staple food for hundreds of millions of the world's poorest people who live in the semi-arid regions of Africa and India where yields are uncertain and famine is common.

Triticale is another cereal that appears to hold the promise of increased production in areas that are marginal for wheat; for example, mountainous regions or those with sandy or acid soils. A hybrid between wheat and rye, triticale, has been described as the first man-made crop. An exceptionally fruitful, collaborative research effort between the University of Manitoba in Canada and CIMMYT in Mexico has achieved extraordinarily rapid improvements in this crop. It is now proving to be well adapted to certain areas in India, East Africa, and Latin America.

Another group of crops of particular importance to people in semi-arid and tropical areas is food legumes and oilseeds. These provide much needed protein and oil, and help to maintain an essential amino acid balance in the diet. Cowpeas, pigeon peas, chick-peas, broad beans, and lentils in particular have previously received little research attention, yet there are possibilities of increasing yields and developing better adapted varieties of these crops.

Still another priority area is tropical root crops, which have also been comparatively neglected. One of the most important of these is cassava (a dietary staple for 300–500 million people in the humid tropics). Cassava has a very large potential for increased yield.

In view of the danger of food shortages in some of the world's most heavily populated areas, particularly the rice-growing regions of South and Southeast Asia, there is a need to intensify food production in these regions by improving cropping systems. In the wet tropics two or more crops, including rice but also many other dryland crops, are often grown on the same land in the same year, either one after the other or simultaneously. In addition to the rice-based cropping systems program, dryland cropping systems projects are being developed in Latin America and Africa in an attempt to solve some of the extremely difficult problems caused by the breakdown of traditional agriculture based on shifting cultivation.

A small but important component of IDRC's program involves critical basic research supporting the more applied work: identifying drought resistance; storing cassava germ plasm; making synthetic stimulants for germinating parasitic witchweeds; and, following upon the success of triticale, attempting to hybridize maize and sorghum. Much of this work is being done in Canadian institutions. At CIDA's request, some of these projects, and other important projects in the triticale and root crop networks, have been funded by CIDA and managed by IDRC on behalf of CIDA.

In the following chapters, the five main research networks that IDRC is supporting are described. Each network is treated on a geographical basis, starting with projects in the Americas, and proceeding eastward to projects in Africa, the Middle East, and Asia.

Sorghum and Millets

Sorghum (*Sorghum bicolor*) and millets are small-seeded grass-like cereal grains. There are several species of millets of which pearl millet (*Pennisetum americanum*) and finger millet (*Eleusine coracana*) are the most important. They are more drought-resistant than maize, so they are mainly grown without irrigation in the semi-arid regions. IDRC placed a strong emphasis on the improvement of these crops. A network of projects was established in cooperation with developing country scientists, and IDRC also assisted substantially in the establishment of a new research centre, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), at Hyderabad, India.

ICRISAT was allocated the world mandate for the improvement of sorghum, pearl millet, pigeon peas, chick-peas and groundnuts. It also has programs for the improvement of farming systems and for socioeconomic studies. Therefore, ICRISAT became the logical scientific coordinating centre for the network of sorghum and millet improvement projects that were developing throughout the semi-arid tropics.

Latin America and Canada

In Central America, the International Centre for the Improvement of Maize and Wheat (CIMMYT) carried out a small high-altitude sorghum improvement project as an adjunct to its main program on maize and wheat. Because CIMMYT had access to research stations at both low and high altitudes it was able to intercross some of the cold-tolerant, late-maturing, photosensitive, high-altitude material introduced from Ethiopia and other similar areas with higher-yielding, photoinsensitive, earlier-maturing material from the USA and elsewhere. This approach proved successful in producing a range of germ plasm that was adapted to cold temperatures and could be used for further breeding work in countries such as Ethiopia, Kenya, Uganda, and Rwanda where high-altitude sorghum is grown. It also opened up the possibility of growing sorghum in some of the high-altitude areas of Central and South America.

To support the applied sorghum and millet improvement projects in the developing countries, IDRC encouraged some basic research in well-equipped laboratories in developed countries to attempt to solve some of the more fundamental problems limiting production. Because the main limiting factor in the semi-arid areas is drought, two Canadian universities undertook to study drought tolerance. In a project at Laval

CIMMYT researchers are attempting to breed sorghum varieties that are cold tolerant for use in high altitudes in Central and South America and in East Africa.

University, methods of screening large quantities of breeding material for drought tolerance at an early age were investigated in collaboration with a sorghum-breeding project at Bambey, Senegal (described later). At the University of Saskatchewan, in Saskatoon, a more fundamental approach was used by studying the various plant hormones involved in the drought-tolerance mechanism and their balance and interactions within the plant. In this very complex research area, the project succeeded in identifying and quantifying various hormones, and in doing so developed a methodology that could perhaps be used for screening breeding material to determine its degree of drought tolerance.

Another project at the National Research Council of Canada's Prairie Research Laboratory at Saskatoon involved useful preliminary work on exploring the possibilities of making a cross between sorghum and maize using modern tissue culture techniques. (The Indian scientist who did the work in Saskatoon hopes to continue the project on his return to the Punjab Agricultural University in India.) It was thought that if this "long shot" came off, the resultant hybrid might combine some of the best characters of both sorghum and maize. For instance, if the drought tolerance, hardiness, and disease resistance of sorghum could be combined with the high-yield, desirable grain characters, and bird resistance of maize, the result might be a very valuable new crop.

Africa

Bambey Research Station, situated about 120 km from Dakar, Senegal, is the main research station of the Institut Sénégalais de Recherches Agricoles (ISRA).

The original objective of the IDRC-supported sorghum-breeding project at Bambey was to breed sorghum cultivars of medium maturity length that could supplement and perhaps in time replace the slow-maturing traditional cultivars grown in the area immediately to the south of Bambey. These very tall photosensitive varieties did not mature until after the end of the rainy season, by which time the ground was too hard to be plowed in readiness for the following season. Because the farmers could only plow the land sometime after the first rains were received in July, this meant that planting was delayed, and the subsequent yields were considerably lower than could have been achieved by earlier planting.

Rapid progress was made, particularly with the earlier 100-day material. Some promising lines were produced that gave yields of up to 8 tonnes per hectare (t/ha) in small plots, and these were ready for testing in farmers' fields within four years of the start of the breeding program. Some grain mold resistance was also bred into this material as grain molding is one of the problems of harvesting before the end of the rains.

One of the main limiting factors to agricultural research in the francophone West African countries is the shortage of trained national scientists. Therefore, a training program for 14 students from several West African countries was organized as a sandwich course. The students did their course work at Laval University in Canada and spent three months in each of two years at Bambey doing their research for the MSc degree. This arrangement had the advantage of combining an exposure to the rigorous course work training program of a North American university with research in an environment very similar to that of their home countries.

The sorghum project with the East African Agriculture and Forestry Research Organization (EAAFRO) based at Serere Research Station, Uganda, was designed to produce improved sorghum varieties and hybrids in both the white-grained and brown-grained groups to meet the needs of all the East African countries. The project was later extended to include the important finger millet (*Eleusine coracana*) crop. Progress was made under the leadership of Ugandan scientists, and high-yielding sorghum cultivars and hybrids were produced and tested throughout East Africa. Some of the good grain sorghum selections gave yields up to 7 t/ha in small plots and they proved popular with the farmers. Some finger millet seed was sent from Uganda to the United States and exposed to radioactivity to induce mutations. On return to Uganda, the seed was grown out, and a male sterile mutation was discovered. This mutant is now being used to form random mating populations of this crop and shows promise of further improvements in disease and lodging resistance and in yield. A white-grained type has also been developed and may prove to be popular in some areas.

Another project at Makerere University, Uganda, was aimed at combining breeding, agronomic, and plant physiological work on sorghum, finger millet, and pigeon pea as a backup to the breeding project at Serere. An important objective of this project was to develop indigenous research capabilities by training graduate students within the project. Some 12 students have been trained to the MSc level, including the sorghum breeder who is now running the Serere project. Four of the MSc graduates have gone on to complete their PhD; one at Makerere, one at Nairobi University where he is now in charge of the IDRC-supported pigeon pea project, and two in North American universities.

Because sorghum, finger millet, and pigeon peas are often grown in mixtures in East Africa, an important aspect of the project was the investigation of the various crop combinations forming the mixtures. Several studies of various crop mixtures were carried out and these indicated that the total production from both components of the mixtures is usually considerably higher than the production of either crop in pure stand. For instance, a mixture of sorghum and beans gave up to 55% greater total yield than the two crops grown in pure stand. The physiological studies indicated that the reasons for this increased production were probably that the mixtures were able to utilize the available environmental resources more efficiently than the crops in pure stand, particularly when the maturity periods of the component crops were different. In other words, in a mixture such as sorghum and beans, the beans could grow and mature while the sorghum was still young, therefore producing an early crop without competing very strongly with the sorghum which matured later. Also, the nitrogen-fixing capability of the leguminous crop might contribute to both the legume and the cereal nutrition. Another advantage of the crop mixtures was improved ground cover, which helps protect the soil from rainfall erosion and from weed infestation.

A similar project with the University of Dar es Salaam, Tanzania, was designed to study intercropping under local conditions. A wide range of crops was investigated, particularly sorghum, pearl millet, maize, soybeans, and cowpeas. Because comparatively little field research had been done by the majority of the faculty staff before this project was established, it was also designed to assist in the development of a strong program of field experimentation at the faculty, and in the training of graduate students to become research workers both in the faculty and throughout the Tanzanian research services.

With the assistance of a Canadian adviser, progress was made in selecting improved cultivars of all these crops for growing both in pure stand and intercropped under Tanzanian conditions, and, as well, suitable combinations of cultivars were worked out with the appropriate fertilizer and insecticide applications. A demonstration of these results given for the Prime Minister and other Ministers by the Tanzanian scientists impressed upon them the importance of multiple cropping

An example of intercropping sorghum and sweet potatoes.

systems in a country where, until recently, monoculture had been officially encouraged.

By demonstrating the potential of sorghum as a grain crop, the project became the main cause of a presidential decree that sorghum, rather than maize, should be the officially recommended crop in certain dry areas of Tanzania where maize had been previously encouraged but was unsuited to the conditions. The project undoubtedly had the effect of encouraging the faculty scientists to participate in field research and in training students at the undergraduate and graduate level. Six of these students are now being sent overseas for further graduate training. A weakness of the project was its failure to involve faculty staff members with the actual problems of Tanzanian farmers, but this weakness can be remedied in the future.

A symposium on intercropping in semi-arid areas was sponsored jointly by the Faculty of Agriculture, Forestry and Veterinary Science, University of Dar es Salaam and IDRC in 1976. Eighty-eight scientists from 14 countries attended, and summaries of the papers presented were published by IDRC (IDRC-076e). The surprisingly wide interest in intercropping research, and the very limited research effort previously applied to it were features of the symposium. The widespread increased activity devoted to intercropping research since the symposium results were published indicates that the symposium had a pronounced catalytic effect on intercropping research throughout Africa.

Rwanda, a small country in Central Africa, has extremely severe problems with population pressure on the limited fertile land that is available, and with undernourishment and malnutrition. There is an urgent need to improve the production of food crops, particularly in the high-altitude areas above approximately 2000 metres (m). IDRC is supporting the Rwandan Institute of Agricultural Sciences (ISAR) in a program to introduce sorghum, triticale, sunflower, and rapeseed germ plasm, and carry out some selection and agronomic work on these crops. Rwanda has very few trained agricultural scientists, therefore, an important feature of the program is the training of Rwandan scientists to work within it.

Good progress was made in establishing contacts in other projects within the IDRC-supported sorghum and triticale networks, and with ICRISAT and CIMMYT, and in obtaining germ plasm from these sources as well as sunflower and rapeseed from Canada, the USSR, and other countries. The preliminary work of testing and selection indicates that there are possibilities of improving the yields from all these crops, and that they may make a real contribution to food production in the country.

Ethiopia is one of the key areas for sorghum. It is probably the centre of origin of the crop, and an enormous diversity of cultivars, ranging from cold-tolerant cultivars adapted to conditions at over 2000 m altitude in the highlands to heat-tolerant types grown on the fringes of the Danakil Desert, are grown there. About one million hectares of sorghum are grown annually in Ethiopia, and many of its 28 million people are dependent on the crop for their staple food supplies.

Little scientific research had been done on Ethiopian food crops until the establishment of Alemaya Agricultural College, now the Agriculture Faculty of the University of Addis Ababa, by a team from Oklahoma State University with United States Agency for International Development (USAID) support in the early 1950s.

The crop scientists from Oklahoma started some sorghum collecting and screening work, and they also arranged for the training of several outstanding Ethiopian scientists to the PhD level. Two of these scientists, the then Dean of the Agricultural College, and the Head of the Crop Science Department, were plant breeders, and they were particularly concerned about the improvement of the Ethiopian sorghum crop.

The Institute of Agricultural Research (IAR), the national agricultural research service that had been established with assistance from the Food and Agriculture Organization of the United Nations (FAO) and the United Nations Development Program (UNDP) at about the same time, had allocated national responsibility for sorghum improvement to Alemaya Agricultural College. Therefore, the Dean approached IDRC for assistance in expanding the sorghum improvement program at Alemaya.

The Head of the Crop Science Department was to be the project leader and chief sorghum breeder; however, because of his heavy responsibilities as Head of the Department, a young Canadian scientist was sent to Alemaya to help him, and the project commenced in May 1973. Four outstanding Alemaya graduates were recruited to work as research assistants on the program, and later to go for graduate training overseas. The University policy that all potential graduate students should do a full year's research before going overseas was undoubtedly of value to these students as they were able to gain considerable experience while working on the program and were able to demonstrate their ability and interest before beginning their training in Canada.

Under strong leadership rapid progress was made by screening the many cultivars already collected and testing these in the prenational and national yield trials. Two high-yielding cultivars, Alemaya 70 and Awash 1050, were identified and seed was multiplied for issue to the farmers. These cultivars, under experimental conditions, have given yields of approximately 5–8 t/ha. The average on-farm yields of the traditional cultivars are about 1 t/ha.

A weakness of the project was the lack of a formal link with the national Extension and Project Implementation Department (EPID). As a result the improved cultivars that were developed in the project were rather slow in being introduced to the mass of small farmers. However, the project leader did his best to develop informal links with EPID, and he also organized a number of demonstration plots on farmers' fields to show the improvements that could be obtained when the new cultivars were combined with a little fertilizer and good agronomic practices.

With the advice of an experienced Canadian food scientist, a start was made on the screening of the sorghum selections for "enjera" of good cooking quality and taste. (Enjera is the local flat bread made from fermented dough.)

The severe drought and famine in the early 1970s indicated that there was an urgent need for the improvement of the lowland sorghums as well as those in the highlands. In 1975, the project leader began to plan for a national sorghum improvement program, with its headquarters at Nazareth, about 80 km to the southeast of Addis Ababa. This proved to be a good centre for carrying out an improvement program in both the high-altitude and low-altitude areas. In addition to Alemaya for the high-altitude, two other high-altitude substations and four low-altitude substations were selected for testing the improved cultivars in collaboration with the IAR. The second phase of the project was approved on this basis in January 1976 as a joint program between the IAR and the University.

One of the graduate students returned with his MSc in agronomy from Guelph University, Canada, and gave strong support to the project leader in the expansion of the program. A cultivar, named Kobomash 76, which showed promise of performing well in the low-altitude areas, was released for farmers' use during 1977. In addition to a comprehensive crossing program for suitable plant characteristics, disease resistance, high-yield, and a rigorous testing program throughout the country, the project also started a systematic process of collecting all the locally grown cultivars from throughout Ethiopia. This rapidly became one of the most important germ plasm collections of sorghum in the world, and particular interest was aroused when scientists at Purdue University in the USA found that two of the local sorghum cultivars were much higher in lysine, an essential amino acid that is more often deficient in cereal-based diets.

A number of insect pests cause severe damage to sorghum. One of these, the shoot-fly (*Atherigona* spp.) is particularly widespread and difficult to control. In 1977, ICRISAT requested IDRC support for a concentrated study of the shoot-fly by the International Centre for Insect Physiology and Ecology (ICIPE), Nairobi, Kenya. ICIPE has excellent resources for more basic research on the population dynamics and biology of the shoot-fly than is possible at ICRISAT. Also, because there appear to be different species of shoot-fly in Africa than those in India, research on the African shoot-flies must necessarily be done in Africa. The work at ICRISAT and ICIPE has already confirmed that there are possibilities of selecting sorghum-breeding material for resistance to shoot-fly attack.

Middle East

In the Middle East IDRC supported an important initiative by the Ford Foundation-sponsored Arid Lands Agricultural Development (ALAD) program. With its headquarters in Lebanon, this small group of scientists succeeded in establishing a very effective informal collaborating network of research workers in 13 countries.

The group carried out some research with the aim of developing high-yielding varieties of wheat, barley, triticale, maize, sorghum, millets, broad beans (*Vicia faba*), lentils (*Lens culinaris*), and chick-peas (*Cicer arietinum*) in collaboration with the government research workers in Lebanon. They also arranged the distribution and testing of germ plasm of these crops in all the countries of the region, and they arranged periodic workshops to compare results and evaluate the selected varieties. An important part of their activities was in training middle-level plant breeding technicians in the practical techniques of plant breeding at the Lebanese Research Station. In this way a network of contacts was built up at the junior scientist level at research stations throughout the region.

IDRC's contribution was through funding of the sorghum, millet, and grain legume part of the program. Two advisers were provided, one to work on millet and the other on grain legumes.

Asia

A number of minor millets are widely grown in India. They generally occupy mountainous land that is unsuitable for other cereal crops, and are important for the tribal people who subsist on these marginal lands. There is little doubt that the present production of about 1.8 million tonnes of grain from these crops could be rapidly increased by determined crop improvement programs.

Therefore, IDRC is supporting the All India Coordinated Millet Improvement Project in programs at five breeding centres to improve Kodo millet (*Paspalum scrobiculatum*), Foxtail millet (*Setaria italica*), Little millet (*Panicum miliare*), Proso millet (*Panicum miliaceum*), and Barnyard millet (*Echinochloa frumentacea*).

Two projects were developed in Southeast Asia; one on semi-arid crops at Khon Kaen University in Northern Thailand, and the other on sorghum and maize at the University of Papua New Guinea.

The project in Thailand concentrated on the improvement of sorghum and groundnuts, in close collaboration with ICRISAT, and soybeans, in cooperation with the International Soybean Program (INTSOY) at the University of Illinois, USA. Good progress was made in introducing and testing a wide range of germ plasm and in agronomic studies to determine the best ways of growing these crops, both in pure stand and intercropped. Some difficulties were encountered in the field experimentation program due to the unevenness of the soil on the University farm. However, progress was made toward the solution of these problems by a fruitful collaboration between soil scientists, agronomists, and plant breeders.

A researcher in Senegal examines sorghum plants in a shoot-fly resistance experiment.

Training of graduate students formed an important part of the project. Several students were sent to ICRISAT and other centres for further training both in short courses and for MSc degrees.

- The project in Papua New Guinea has made progress in collecting and evaluating sorghum germ plasm from ICRISAT and elsewhere, and maize germ plasm from CIMMYT, from Australia, and from other sources. Two graduate students, one from Papua New Guinea and the other from the Gilbert and Ellice Islands, did the work, and a considerable number of intercropping studies, particularly with sweet potatoes, were also carried out.

Parasitic Weeds

One of the serious constraints limiting cereal production in the developing world is the parasitic witchweed, *Striga*. This weed is widely distributed in sorghum-growing areas, especially in Africa and India, and it also attacks other crops, particularly pearl millet, maize, rice, sugarcane, and cowpeas. The weed is extremely difficult to control by normal methods of cultivation as it produces very large numbers of small seeds that can remain dormant in the soil for long periods. Normally, the seeds will not germinate until they are stimulated by an exudate from the root of a susceptible host plant. After germination the parasites grow and attach their roots to the roots of the host plant and extract their nutrients from the host.

The loss of production due to *Striga* is difficult to measure accurately, but in 10 seasons of observation in Northern Nigeria the region's annual loss of grain yield due to *Striga* was estimated to be at least 760 000 tonnes — worth about $70 million per year at current prices.

If relatively cheap and efficient *Striga* control methods, which could be applied by small farmers, can be developed, they should have considerable effects in increasing food production.

In an IDRC-supported project at the University of Sussex, UK, chemists have succeeded in producing synthetic compounds that will induce *Striga* seeds to germinate. Lacking a host plant, the weeds soon die. As an unexpected bonus, another parasitic weed, broomrape (*Orobanche* spp.), which infests broad beans, lentils, tomatoes, potatoes, marrows, squashes, and many other crops in parts of the Middle East, North Africa, Asia, and elsewhere, was found to be equally susceptible to the chemicals.

Initial testing of the germinators was arranged at ICRISAT, at Tel Amara, Lebanon, and at Giza, Egypt. Once the compounds have been shown to be effective in field tests, the next step will be to interest a manufacturer in their large-scale production.

To help with the testing of the germinators, and to strengthen the existing *Striga* research program at Ahmadu Bello University, Zaria, Northern Nigeria, IDRC has funded a young Canadian University Service Overseas (CUSO) volunteer. The program has already obtained promising levels of *Striga* control with the germinators, and a survey is being done on the distribution of *Striga* species and strains in Northern Nigeria.

Because Sudan is one of the largest sorghum- and millet-growing countries in Africa, with over 3 million hectares under cultivation, IDRC has also supported a project with the Agricultural Research Corporation (ARC) of the Sudanese Ministry of Agriculture. The ARC, in collaboration with the Faculty of Agriculture of the University of Khartoum, will establish an extensive program of research on *Striga* control. This program will be led by an experienced Sudanese scientist, and will include breeding *Striga*-resistant varieties of sorghum and millet, testing the new germinators under Sudanese conditions, investigating the distribution of the species and strains of *Striga* in Sudan, and evaluating other possible methods of control.

IDRC is also supporting an ICRISAT weed scientist to work in West Africa. He will be part of the ICRISAT sorghum and millet improvement team based in Upper Volta, and will breed *Striga*-resistant sorghum and millet and test the germinators under West African conditions. In addition, he will coordinate *Striga* research activities throughout Africa.

Triticale

Triticale can be described as the first successful "man-made" cereal crop. It is the product of an intergeneric cross between *Triticum* (of which wheat is a member) and *Secale* (of which rye is a member), getting half of its name from each parental genus.

Canada and Latin America

Although a sterile plant grown from a wheat/rye cross was reported as early as 1875 in Scotland, and plant breeders in several European countries had experimented with triticale since, it was not until 1954 that plant breeders at the University of Manitoba, Canada, brought together for the first time several primary triticales from individual researchers and research stations around the world. A vigorous breeding program was pursued at Manitoba, and the many new wheat/rye crosses that were made led to the development of the first triticales that gave promise of becoming a potential crop. Meanwhile, plant breeders at the International Centre for the Improvement of Maize and Wheat (CIMMYT) in Mexico, where the new high-yielding varieties of wheat had been bred, became interested in the potential of triticale. Close collaboration was developed with scientists at the University of Manitoba, and some of the Manitoba material formed the start of a breeding program at CIMMYT.

The original Manitoba introductions were not well adapted to Mexican conditions as they were late in maturing, tall, and susceptible to lodging, and most of the seed they produced was shriveled and sterile. Also, they were susceptible to disease (particularly stripe rust) and were daylength sensitive and low yielding.

But in 1967, a breakthrough in the development of triticale occurred when a stray wheat pollen grain fertilized a triticale plant in a neighbouring plot. Its triticale progeny indicated that in the act of fertilization it had dwarfed, introduced partial photoperiodic insensitivity, and completely overcome the sterility barrier that had inhibited progress in triticale improvement for decades. Nature had succeeded where scientists had struggled for years!

The cross was named Armadillo, and many of the new plump-seeded, fertile, short-strawed, disease-resistant, high-yielding triticales have an Armadillo parentage. This breakthrough indicated that triticales could be a potential commercial crop to rival wheat in certain areas of the developing world and this led to a large increase in the breeding programs.

In 1970, the Canadian International Development Agency (CIDA) asked IDRC to manage a $3 million program to develop the Manitoba/CIMMYT triticale as a new cereal crop that would benefit malnourished people in the developing parts of the world. As a result, a considerable expansion of the breeding program at both the University of Manitoba and CIMMYT was undertaken, and many new crosses were made, in efforts to give triticale a wider genetic base. At the same time, triticale screening, disease, and yield nurseries were distributed to many of the cooperating countries that were already receiving CIMMYT wheat material. For instance, in 1974, a total of 309 nurseries were distributed to 62 countries.

By taking advantage of the highly organized and far-flung CIMMYT wheat-breeding and testing organization, one of the largest and most comprehensive crop breeding programs ever undertaken moved triticale from a scientific curiosity to a commercially viable crop in less than 10 years. In 1968, the best triticale yields only amounted to approximately half of the best wheat yields. By 1973–74, the average yield of the five best triticales in the international triticale yield trials throughout the world was 15% higher than the best wheat yields in the trials.

Like its rye parent, triticale has demonstrated an adaptation to acidic soils in several areas of the world. It also appears to be more tolerant than wheat to aluminum toxicity. One of its main advantages over wheat is its superior disease resistance; for instance, so far it has proved more resistant than wheat to leaf blotch, powdery mildew, the smuts, and *Septoria tritici*. On the other hand, it lacks adequate resistance to other diseases including *Fusarium* head blight, nivale, bacterial stripe, several virus diseases, and some root-rotting and leaf-destroying organisms. It can also be susceptible to ergot, a fungus that attacks rye in temperate zones, but has not been identified on rye or triticale in the tropics. Because it is a new crop, there are possibilities that as the area on which it is grown is extended, more serious strains of certain diseases may develop. However, it is estimated that at least 100 000 hectares of triticale are being grown worldwide, and few serious disease problems have been encountered so far.

The crop appears to show particular promise for increasing food production in those parts of the developing world that are marginal for wheat production; for instance, in the high-altitude areas of Central and South America, Eastern Africa, and the Himalayan chain from Afghanistan to Nepal, and lower altitude areas in the Mediterranean and Middle East, where *Septoria* is serious. It is unlikely to compete directly with wheat for bread-making because of the latter's superior bread-making qualities. Wheat contains a protein called gluten that forms a dough that is very strong and elastic. This dough can be baked into bread. It is more difficult to make acceptable bread from triticale flour using traditional bread-making methods. However, mechanical development of the dough, by intensive rolling or other methods, allows acceptable bread to be made from triticale flour. Alternatively,

Cooking enjera, a local flat bread, in the traditional manner but using a triticale flour mixture.

triticale flour can be blended with wheat flour producing very satisfactory results using traditional bread-making methods. In addition to bread, triticale gives good results when used in making foods such as pastas, breakfast cereals, pancakes, tortillas, and chapatis. Triticale biscuits are now on sale in Canadian supermarkets. It can also be used in the brewing and distilling industries. In addition, it is proving extremely important as a grain crop for animal feed and as a forage crop.

The nutritional value of triticale appears to be equal to or slightly better than that of wheat. The average protein content is marginally higher than the mean protein content of the most commonly grown wheats, but the content of the amino acid lysine, which is often deficient in cereal-based diets, appears to be higher than that of wheat.

Feeding trials with animals have shown that triticale is at least equal to and often superior to wheat in biological value.

In addition to the University of Manitoba's important contribution to the cooperative breeding program with CIMMYT, already described, the University has been undertaking more fundamental studies on the cytogenetics and physiology of triticale, first with CIDA and then with IDRC support. A considerable amount of work has been done on improving the methods of culturing the triticale embryos and treating them with colchicine to double the chromosome number. Several graduate students from triticale programs in the developing countries have been trained in the University of Manitoba program, and some of them have assisted in these studies.

Because the winters in Manitoba are too cold for triticale to be grown as a winter crop, the University of Guelph, with IDRC support, has undertaken a program to develop winter triticales. Winter-sown triticales are considered to be particularly important for areas such as Turkey, Afghanistan, the Himalayan region, and parts of the high plateau in North Africa that have cold rainy winters. In these areas, spring-sown triticales may have too short a growing season to yield satisfactory crops, whereas spring triticales sown in the winter may not survive the cold. Progress has been made at Guelph in screening the available material for winter hardiness and in breeding new winter triticale lines. The winter survival and yield of the most advanced winter triticale lines are already considerably better than those of either the spring triticales or winter wheats. Further improvements are expected.

Scientists, at the Catholic Univeristy of Chile, continued their excellent program of triticale development with IDRC support. In the 1976–77 season, in 16 irrigated experiments throughout the country, the average yield of 6064 kilograms per hectare (kg/ha) of the best triticale lines was 47% above the wheat check, at 4118 kg/ha. In one experiment, the triticales gave a maximum yield of 12 337 kg/ha from small plots, compared with a wheat yield of 7550 kg/ha. The average protein content of the best triticale lines was nearly 15%, considerably higher than the protein content of the wheat check of just under 12%. A full program of agronomic experiments was also carried out, and some forage trials gave encouraging results.

Africa

Wheat has been an important crop in the highlands of Ethiopia since time immemorial but there are considerable problems in growing the crop, particularly on the acid soils found in many parts of the country. Also, wheat suffers from numerous diseases prevalent in Eastern Africa.

The Institute of Agricultural Research (IAR) in Ethiopia began a modest triticale improvement project in 1972 with IDRC support. Some preliminary testing of the triticale lines bred by CIMMYT, in conjunction with the University of Manitoba, had been carried out before 1972 with promising results. The project enabled the IAR to undertake a larger selection program to determine whether the crop could make a contribution to the solution of some of Ethiopia's severe food problems. At the same time, cooking and acceptability trials were conducted to find out whether the crop would be acceptable as a food for Ethiopian farmers and their families.

In the 1976–77 season, the CIMMYT cultivar, Bacum, yielded 8.7 t/ha in one small plot experiment. The best triticale lines gave average yields of nearly 5 t/ha over 11 locations, compared with the wheat check yield of just over 3 t/ha. These are relatively high yields under rain-grown conditions. One reason for the yield advantage of triticale appeared to be its good disease resistance, particularly to *Septoria* and stem rust.

A previous general manager of the IAR made a personal attempt to introduce triticale as a new crop in the Endibir region of Ethiopia, which had been seriously affected by food shortages. Thanks to his efforts, some of the farmers started growing the crop, and their wives started preparing it as a porridge, which is a common dish in that area. At the same time, a female technician of the IAR gathered a group of housewives together to try to prepare enjera, the local flat bread, from triticale flour. After some cooking and tasting trials they found that they could prepare acceptable enjera from pure triticale flour or from various blends of triticale with wheat, sorghum, or teff, all of which are staple food grains in Ethiopia. This is thought to be the first example of the adoption of triticale as a human food in the developing world.

Cooperation has been maintained with both the University of Manitoba and CIMMYT. Ethiopian scientists have also been trained in Manitoba to work on the project.

A similar project with the National Plant Breeding Station, Njoro, Kenya, received support from Canadian scientists through a CIDA contract with the University of Manitoba. Again, impressive progress was made, and the best triticale selections have out-yielded the bread wheats, durum wheat, and barley by at least 20% in a good season and by about 40% in dry years. It appears that the yield advantage of triticale is again due to its superior disease resistance and to its ability to tolerate acid soils. Several selections are now at the seed multiplication stage, and some of them have already been grown in quite large areas of up to 40 ha. The Government of Kenya has recently decided to encourage large-scale triticale production in areas marginal for wheat. Trials of composite flours containing up to 50% triticale and 50% wheat have produced bread similar to 100% wheat in baking tests.

Asia

IDRC has supported a triticale project at the G.B. Pant University of Agriculture and Technology at Pantnagar in Northern India since

1974. The University has had an extensive program of triticale trials, both in the hills under rain-fed and low fertility conditions, and on the plains under irrigated and high fertility conditions. The results have been encouraging, with the triticales giving considerably higher yields than the wheat checks in the hills. For instance, in the 1976–77 season, the five highest-yielding triticales gave from 2–2.2 t/ha, whereas the wheat checks gave 1.9–2 t/ha. Many crosses were also made between various triticales and wheats, and cytological and morphological studies were performed. A comprehensive program of agronomic experimentation was carried out, and some 263 demonstrations were planted on farmers' lands, and 2710 mini-kit tests were supplied, each with five triticale varieties and appropriate fertilizers and instructions. A taste panel was set up to assess the acceptability of chapatis made with triticale. There was good response to a 25% mixture of triticale flour with wheat flour, but with 50 or 75% triticale flour, the appearance and texture were less acceptable, although the flavour seemed to be acceptable.

Food Legumes and Oilseeds

Overall food shortages in developing countries are only one aspect of the world food problem. Many of the poorest people in these countries suffer from varying degrees of malnutrition caused by an imbalance in their diet. People who rely mainly on starchy foods, such as root crops and plantains, are particularly liable to protein deficiency. Although those people who rely on cereals such as maize and sorghum for their staple diet are less likely to suffer from overall protein deficiency, these crops tend to be low in some of the essential amino acids, particularly lysine, and this deficiency can give rise to serious malnutrition, especially among postweaning children.

Food legumes such as pigeon peas (*Cajanus cajan*), cowpeas (*Vigna unguiculata*), chick-peas (*Cicer arietinum*), broad beans (*Vicia faba*), and lentils (*Lens culinaris*) contain considerably more protein than most other food crops. In addition to their high protein content, they contain high levels of some of the amino acids, particularly lysine. This makes them excellent complementary crops to be grown with cereals. Their symbiotic relationship with the nitrogen-fixing rhizobia bacteria in their root nodules, which is a main reason for their high protein content, also enables them to survive and flourish on soils containing low levels of nitrogen, and even to add to the nitrogen levels and overall fertility of these soils.

Available statistics indicate that during the past 20 years per capita legume consumption in Asia and Africa has been declining while the proportion of other foods consumed has increased. So it appears that the nutritional quality of the diet of the poorest people may be deteriorating. In addition, there are serious deficiencies in fats and oils in the diets of many of the poorer people of the world. For instance, in India the average intake of vegetable fat or oil is only about a quarter of the desirable level. IDRC is supporting a network of research projects designed to increase production of food legume and oilseed crops.

Latin America

One of the first of these projects was a grain legume improvement program for the Caribbean area based at the University of the West Indies in Trinidad. This work concentrated mainly on breeding an early-maturing, high-yielding, dwarf, photoinsensitive, disease-resistant type of pigeon pea with the large seed size desired by the West Indian market. In addition, some work was done on selecting disease-resistant *Phaseolus* beans and cowpeas. With the appointment by the University of an experienced legume breeder supported by IDRC, the pigeon pea breeding program has made excellent progress, and what is virtually a new crop ideotype has been developed. The traditional pigeon pea cultivars grown in the West Indies are large bushy indeterminate photosensitive types that only flower and fruit at Christmas time. Therefore, the West Indians have developed the custom of eating green pigeon peas at Christmas only. The new types give much higher yields of up to 4000 kg/ha of fresh peas, and can be planted as a row crop at close spacing at virtually any suitable time of the year, and harvested at any time. This should allow farmers to obtain a good profit from growing the crop almost throughout the year and reduce the present need to import large quantities of pigeon peas.

Long before the known history of the Inca Empire in the Andean Highlands of South America a variety of wild food plants, still little known today in the Western world, were domesticated and became the principal food sources of the local people. One of these, which is still an important crop in the Andean region, is called quinoa (*Chenopodium quinoa*).

Although quinoa is not a legume, it is high in protein and vitamins, and there appear to be good possibilities of increasing production by scientific breeding methods. IDRC is supporting the Bolivian Institute of Agricultural Technology (IBTA), the government agency responsible for agricultural research, in a program designed to improve the production of quinoa. The Inter-American Institute of Agricultural Sciences (IICA), a regional agricultural research organization, and the Technical University of Oruro will collaborate in the research. A similar small project is being supported in Colombia.

Quinoa, a traditional crop of the High Andes, is not a legume, but it is rich in protein and shows great promise of increased yields.

Africa

The semi-arid Sahelian countries of West Africa are extremely dependent on three crops for their staple food: millet, sorghum, and cowpeas. Cowpeas are often interplanted with the millet or sorghum, and are also grown in pure stand on some of the sandy dune soils in areas that are too dry even for millet. Because cowpeas can produce a crop in as little as 60–70 days, they can avoid drought even more successfully than the millet crop. Apart from a limited amount of breeding work in the region, little research on cowpeas has been carried out.

The International Institute of Tropical Agriculture (IITA) has the world responsibility for cowpea improvement, and its core breeding program at Ibadan, Nigeria, has already collected a wide range of germ plasm comprising material of considerable genetic diversity. Material has already been bred that has improved yield potential and some resistance to pests and diseases. Because the semi-arid areas are the main cowpea growing areas, it is important for IITA to be able to test its material widely throughout these areas. A breeding program in the semi-arid areas is also important to ensure adaptability of the new material to those conditions. Upper Volta is ideal for this purpose because the prevailing agroclimatic conditions are typical of a large part of the Sahelian region.

An IITA cowpea breeder, based at Kamboinse Research Station, near Ouagadougou, with IDRC support, is working in close cooperation with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) sorghum and millet breeding team. Although the program only started in 1977, rapid progress has been made, and several cowpea cultivars, which are considerably higher yielding than the local cultivars, have already been identified.

One of the most serious limiting factors in cowpea production is insect damage. In one trial, half were treated with insecticide while the other half were untreated; nearly all the treated lines gave yields of over 1000 kg/ha, with the best yields at 1840 kg/ha, whereas only two untreated lines gave a yield of over 100 kg/ha, and several lines gave no yield at all. Therefore, particular attention is being paid to breeding for insect resistance. Similar projects have been approved in the neighbouring countries of Niger and Mali to test the material being selected in the Upper Volta program.

A small project has also recently been approved with the Njala University College in Sierra Leone for food legume improvement. Scientists at Njala have already done a considerable amount of work in cooperation with IITA on food legumes, particularly cowpeas, and they will now test some of the improved selections in multilocational trials throughout Sierra Leone and offer them to farmers for on-farm trials. Members of the Agronomy, Agricultural Engineering, Geography and Environmental Studies, Agricultural Economics and Extension, and Home Economics Departments of the University will be involved in this project, under the leadership of the Dean of the Faculty of Agriculture. Extension workers from the Ministry of Agriculture will also be fully involved in the extension of the improved material and in determining consumer acceptance of the new varieties.

Pigeon pea is an important food legume in the semi-arid areas of East Africa. IDRC has supported research on this crop at Makerere University in Uganda, and at Nairobi University in Kenya. Rapid progress was made in the early stages of the Uganda program, and over 5000 pigeon pea lines were imported from various parts of the world, and screened on the University farm. Early-maturing, determinate pigeon pea lines were developed, which were well adapted to the short rainy season in equatorial regions, and yielded up to 4000 kg/ha, far higher than previous yields. It was found that the pigeon pea crop exhibits a high degree of out-crossing, and that random-mating composites can be used as base populations for breeding purposes. Therefore, a series of breeding populations were formed, and graduate students working in the program studied the heritability of important plant characteristics. Mixed cropping and agronomic experiments were also carried out, and considerable increases in yield over sole cropping were obtained, particularly where the maturity periods of the two crops were different.

A serious leaf spot disease (*Mycovellosiella cajani*), which caused yield reductions of up to 70% in pigeon peas, was also investigated by a graduate student who is now a staff member at Nairobi University and principal investigator in the IDRC-supported pigeon pea project there. The deep rooting habit, drought resistance, and efficient symbiotic nitrogen fixation of the pigeon pea crop make it especially important in the semi-arid areas of Kenya where population pressure, soil exhaustion, and erosion are becoming particularly severe. Again, a large germ plasm bank has been built up both from local collection and from other areas including ICRISAT, which has world responsibility for pigeon pea improvement. A degree of drought resistance has been identified, and high-yielding disease-resistant types have already been tentatively selected and are being increased for distribution to farmers for farmer-level trials. More recently, an extensive agronomic program has been started through which basic agronomic data are being obtained on growing the crop.

Middle East and North Africa

This region has rapidly increasing populations, often high population densities, and sometimes low and decreasing standards of living. Food shortages are becoming more prevalent, and many of the countries are net importers of food products. Also, the spread of the deserts is a constant threat. Three main food legume crops are grown in the region: lentils (*Lens culinaris*), broad beans (*Vicia faba*), and chick-peas (*Cicer arietinum*).

In 1977, the new International Centre for Agricultural Research in the Dry Areas (ICARDA) with its main research station at Aleppo, Syria, was set up with IDRC assistance. This centre has the world responsibility for the improvement of lentils and broad beans. Chick-peas are an ICRISAT responsibility, but ICARDA is an important relay centre for their improvement. ICARDA has taken over the food legume research and development program on these crops started by the Arid Lands Agricultural Development (ALAD) group with IDRC support.

Traditional cultivars of these crops have tended to be low-yielding, limited in their adaptation, and often severely affected by disease. Therefore, the main thrust of the ICARDA program is to continue the crop improvement work started by ALAD. The main emphasis will be placed on increasing the yields of the legumes, with the search for widely adapted, disease-resistant cultivars as important components of the program. Some degree of resistance to the parasitic weed *Orobanche* will also be sought, and selection for drought tolerance will be undertaken.

ICARDA has excellent cooperative relationships and is already exchanging germ plasm with Algeria, Tunisia, Egypt, Sudan, Ethiopia, Yemen, Jordan, Lebanon, Syria, Cyprus, Turkey, Iraq, Iran, Afghanistan, Pakistan, and other countries. Young scientists and technicians from the majority of these cooperating programs have been trained in practically oriented training courses organized either by ALAD or ICARDA. Particular attention will be paid by these scientists to developing improved agronomic practices suitable for each agroclimatic area in their home countries. Also, because the taste preferences of the consumers are quite specific, care will be taken to determine consumer preferences during the early stages of selection of improved material. A limited amount of basic research, which has possible applications to the breeding program, will also be undertaken, including physiological and microbiological studies.

Algeria is one of the countries in the North African region that has a considerable potential for expanding food-crop production, but is experiencing serious difficulties in feeding its people. IDRC is supporting a project that includes triticale, broad beans, chick-peas, and lentils. Although this project was approved in 1973, because of the limited number of scientific staff available in Algeria, progress was slow until IDRC provided an experienced agronomist as adviser to the food legume program in 1976. Progress has since been made in screening the available germ plasm for the local agroclimatic conditions, and in selection for disease resistance and high yields. Excellent results have been obtained by simple agronomic experimentation on spacing, fertilizers, herbicides, and basic mechanization of the crops. As weed control is one of the main problems in Algeria, these improved practices resulted in yields of about 1500 kg/ha of the legumes, compared with normal yields of about 600 kg/ha. In addition, some technicians have been trained in the ALAD/ICARDA programs in Lebanon and Syria, and useful contacts are being developed with other grain legume programs in the region.

Due to the limited area that can be irrigated from the river Nile, Egypt in particular is being forced to import larger quantities of food as its population increases. In recent years the diet pattern has shown a noticeable decrease in protein and fat consumption. Broad beans are the most important food legumes, followed by lentils and chick-peas. Broad beans are eaten at least twice daily and are considered the poor man's meat. Although more than 200 000 ha are cultivated with food legumes, the levels of production are relatively low because of low yields per unit area.

Egypt is fortunate in having a considerable number of well-qualified and experienced research scientists, but research programs are often limited by a lack of finance. IDRC has recently agreed to support two other food legume programs in Egypt and Sudan. The Egyptian Field Crop Research Institute requested IDRC support for a food-legume improvement program for the three crops, to be carried out at three research stations at Giza, Sakha, and Sids, in close cooperation with ICARDA. The Egyptian researchers have already taken part in the ALAD/ICARDA training course on grain legumes.

The program in Sudan will be very similar. Because yields of broad beans are extremely variable in Sudan, particular attention will be paid to the selection of varieties that produce stable yields. Broad beans are normally insect pollinated, and it is thought that one of the reasons for the unstable yields may be the lack of pollinating insects in certain seasons. An attempt will be made to breed self-fertilizing beans that do not require insect pollination. Mass selection will also be carried out within open pollinated populations of beans, which may be maintained in insect-proof cages with beehives to provide the pollinating insects.

One of the world's most important oilseeds is sesame (*Sesamum indicum*) — a crop widely grown by small farmers in tropical countries. Sesame seeds contain about 50% oil of an excellent quality, and about 25% crude protein. One of the main problems in growing the crop is that the seed pods tend to burst open and scatter the seeds as soon as they become ripe. IDRC is supporting a modest project to enable an Israeli scientist, who is a world authority on sesame, to try to breed varieties with pods that do not burst open so readily. Various methods of inducing mutations are being used including gamma radiation and chemical mutagens.

Asia

ICRISAT, based in India, has the world responsibility for pigeon pea, chick-pea, and groundnut improvement. IDRC supported the grain legume program at ICRISAT when it started in 1973 and continued its support until 1977. The germ plasm collection now comprises over 11 000 chick-pea lines, 5400 pigeon-pea lines, and several groundnut accessions. As the Middle East area and Afghanistan in particular are thought to be the centre of origin of chick-peas, further collecting expeditions are being mounted in those areas in conjunction with ICARDA. Efforts are also being made to obtain additional pigeon pea and groundnut lines from Africa and elsewhere.

Although the breeding programs on pigeon peas and chick-peas are still in their early stages, some progress has been made. However, there are very considerable disease problems with both crops. In India, there appear to be three serious diseases: stunt (considered to be caused by a virus); wilt (caused by *Fusarium oxysporum*); and root rot (caused by *Rhizoctonia bataticola*). In the Middle East and North Africa, in addition to the above, *Ascochyta* blight is severe in chick-peas. A *Fusarium* wilt and a sterility mosaic are also serious in pigeon peas. There are signs of promising sources of resistance to these diseases in the germ plasm collection, and the material is being screened for resistance. In addition, selections are being made for resistance to pests, particularly *Heliothis armigera*, the American bollworm, which is a serious pest of both crops. Some intergeneric hybrids of pigeon pea lines with related *Atylosia* spp. have been made, and it has been found that there is less insect damage on these crosses than on pure pigeon peas. It has also been found that these crosses are generally higher in percentage protein than pure pigeon peas.

Some interesting work has been started on rhizobial nitrogen fixation in the two crops. In India, large areas of chick-peas are sown after irrigated rice, and it was found in experiments on the ICRISAT farm that chick-peas, after rice, responded to inoculation with rhizobia resulting in an increase in nodulation, nitrogen fixation, and a 64% increase in grain yield in one experiment from 1090 kg/ha uninoculated to 1801 kg/ha inoculated. Uninoculated plants formed virtually no

At ICRISAT, scientists are breeding varieties of disease-resistant pigeon peas.

nodules. There was no increase in yield from nitrogen fertilizer applied to inoculated plots, indicating that sufficient nitrogen was being fixed by the nodulated plants for the plants' needs.

In general, there was little effect from inoculation of pigeon pea, although there were wide differences in nodulation between different lines. There was, however, severe insect damage to the nodules under some conditions.

In 1976, the Government of Sri Lanka requested IDRC support for improvement of the important food legumes: cowpeas; mung beans (*Vigna aureus*); black grams (*Vigna mungo*); and the cereal, sorghum. The Government is making a major effort to increase production of food crops, particularly in the drier areas of the island, because in recent years the country has become increasingly dependent on food imports.

Sri Lanka already has a limited number of well trained and able research workers, but the resources available for research have been small. IDRC support is strengthening the research already in progress, and enabling much closer cooperation to be developed with scientists in programs at international centres such as ICRISAT, IITA, the International Rice Research Institute (IRRI), and other institutions. Particular attention will be paid to the selection of material of four crops that fit into the bimodal rainfall pattern in Sri Lanka. For instance, some of the grain-grass type sorghums will be introduced from ICRISAT and crossed with the local "scented hill rice" sorghums already grown there. The grains needed are a type that can be used as a rice substitute, preferably with the aroma of the "scented hill rice" variety, and free from red or brown pigments. Promising selections will be tested at research substations and on farmers' fields as part of an IDRC-supported cropping systems project (described later). The research division will also be considerably strengthened by a training program carried out mainly in Canada.

Bangladesh is one of the world's poorest and most heavily populated countries. With 80 million people and a population density of 560/km^2, there is a great need to expand production of all food crops. The staple food, rice, is already receiving research attention, but little research has been done on the food legumes. There appear to be good opportunities for making considerable improvements in these crops. IDRC is supporting the Bangladesh Agricultural Research Institute (BARI) in a program of food-legume improvement. Germ plasm of cowpeas, chick-peas, pigeon peas, green and black grams, and lentils will be imported from appropriate breeding centres, and a vigorous selection for material adapted to Bangladesh conditions will be undertaken at several centres. Particular attention will be paid to the local *Lathyrus* legume, which is widely eaten but contains the toxin, lathyrin. Breeding material will be screened for low lathyrin content, as well as high yield.

A full range of agronomic studies to identify suitable practices for all the recommended material will be carried out. Bangladesh scientists will be trained at ICRISAT, IITA, and in Canada.

As India is also extremely short of oilseeds, several projects have been developed with appropriate Indian research institutes for the improvement of sesame, safflower (*Carthamus tinctorius*), rapeseed (*Brassica campestris*), and mustard (*Brassica* spp.).

The work on sesame is being done at the Tamil Nadu Agricultural University based at Coimbatore in South India, and that on safflower, by the College of Agriculture, Indore, Madya Pradesh. (There appear to be prospects for increasing safflower yields to at least 2 t/ha with a minimum of 40% oil.) The research on rapeseed is being carried out at the G.B. Pant University of Agriculture and Technology, in the State of Uttar Pradesh, and that on mustard at the Haryana Agricultural University at Hissar.

In addition to breeding for high and stable yield, disease resistance, and high oil content, research in Canada has indicated that high levels of erucic acid may be damaging to health, so the low erucic acid rapeseed cultivars developed in Canada will be introduced and crossed with local cultivars to lower erucic acid levels. Attention will also be paid to the glucosinolate content in the cake, which is used for animal feed after expressing the oil, as high glucosinolate levels can be harmful to animals. The work on the oilseed crops is coordinated by the All-India Coordinated Oilseed Improvement Program.

Root Crops

IDRC has supported a large research program on tropical root crops. Although this program includes work on sweet potatoes (*Ipomea batatas*), yams (*Dioscorea* spp.), and cocoyams (*Colocasia antiquorum* and *Xanthosoma sagittifolium*), by far the largest part of the support has been for research on cassava (*Manihot esculenta*). This support has involved a wide range of activities. It includes the provision of funding to the International Centre for Tropical Agriculture (CIAT) in Colombia and the International Institute of Tropical Agriculture (IITA) in Nigeria, for research in Canadian universities and for several programs in government research institutes and universities located in developing countries. These various research activities have been coordinated and integrated in such a way that a network of research activities on cassava has been developed.

The principal reason for supporting cassava, a hitherto neglected tropical crop, was that it appeared to have a higher potential yield, in terms of energy production, than almost any other major crop. Cassava is widely distributed in many tropical countries and is grown mainly as a subsistence crop by small farmers. Total world production exceeds 110 million tonnes of fresh roots. The crop is grown in more than 80 countries although approximately 70% of world production is derived from only five countries: Brazil, Indonesia, Nigeria, Zaire, and Thailand.

During the last decade, the crop has assumed considerable importance as an animal feed with over 15 million tonnes of fresh root equivalent being traded internationally in the dried form. It is also used, to an increasing extent, as an industrial starch and is currently being evaluated in Brazil as the substrate for the production of industrial alcohol that, if economic, could play an important role as a petroleum substitute in certain countries.

Latin America and Canada

IDRC's involvement in cassava commenced early in 1971 when it was asked by the Canadian International Development Agency (CIDA) to manage two grants for cassava research. The first of these entailed the provision of $2.5 million support for the first five years of cassava research at the newly formed CIAT in Colombia. The second grant, $750 000, was for basic research programs in Canadian universities that would provide support for the field program at CIAT.

IDRC commenced its cassava activities by screening the world literature to identify scientists who were either working or had worked on cassava and who could be consulted concerning the development of an appropriate research program. Some two dozen such scientists assembled at CIAT in January 1972, and carried out a detailed state of the art review on cassava. Later a small group of these scientists continued to assist both IDRC and CIAT as an advisory committee to the CIAT program and the development of the international network.

The background literature studies that were prepared as a prelude to identifying the research strategy were further developed by IDRC's Information Sciences Division, which assisted CIAT in developing a comprehensive Cassava Documentation Centre. This entailed collecting the world literature on cassava and preparing a series of abstract volumes that together now cover the more than 3500 known scientific papers dealing with cassava. The abstracts are prepared as an on-going annual service and, in addition, the Documentation Centre publishes a series of monographs and reports by CIAT scientists. IDRC has sponsored a series of more than a dozen small workshops that have dealt with specific aspects and problems of cassava production (IDRC-010e, 020e, 031e (Thai version available), 049e, 063e, 071e, 095e, 096e, and 114e).

The research program at CIAT commenced in 1972 and by the end of 1973 it involved a team that included nine senior scientists. An early phase of the program was the collection of more than 2000 cultivars of cassava germ plasm in Latin America, the region in which the plant evolved. A rigorous selection and testing program has been carried out with this germ plasm and from superior material many thousands of seeds have been produced in an extensive cross-breeding program from which the first promising new hybrids have now reached the large-scale testing stage.

The breeding program is closely supported by agronomic, soil, physiological, entomological, and pathological activities to evaluate the characteristics and adaptability of both the germ plasm collection and the new hybrids being produced. The CIAT program is strongly consumer oriented and has carried out several studies on the economics of cassava production on small farms to assess the economic viability of the directions in which CIAT research is leading. It has also carried out considerable work on various approaches, including storage methods, designed to reduce the rapid deterioration that takes place in cassava after it has been harvested.

Another major facet of the CIAT program is its involvement in training scientists from developing countries. The training program has a small advanced degree component, but focuses principally on applied field training for extension officers and for research workers on cassava teams in national research institutes.

This training element is closely related to the growing network of national cassava research programs in Latin America. In 1976, IDRC provided funds for a network coordinator appointed by CIAT. This coordinator provides a follow-up to the training programs by regularly visiting ex-trainees and assisting them in developing programs of regional trials that evaluate the potential of new CIAT techniques and germ plasm in national research and development programs.

Specific support from IDRC has also been given to national programs on cassava research in Peru, Ecuador, and the Caribbean. In Peru the program focused on economic practices. In Ecuador it helped to finance an agroeconomics survey that was carried out to establish research priorities. The objective of a program in the Caribbean with the University of the West Indies was the promotion of greater production and use not only of cassava, but also of sweet potatoes and yams. Like most IDRC programs located at universities, this one had a strong postgraduate student training function.

Another program in the Latin American region provided funds for graduate students trained at CIAT to work on the use of cassava as an animal feed. This program was carried out in their home countries by students from Bolivia, Peru, and Costa Rica.

A program located in Brazil, has also been provided with funds for the collection of wild cassava germ plasm to evaluate whether any of this has an economic potential and whether wild species can be successfully crossed with cultivated cassava. This program involved the collection and screening of many wild species from Central Brazil and has transmitted seeds from them to CIAT and IITA. Unfortunately, these seeds have all proved to be sterile. The cause of this sterility is now being studied at CIAT while the scientist who gathered the wild cassava collection is now repeating this exercise in the Northeast, which is the second of three locations in the world where wild species related to cultivated cassava abound.

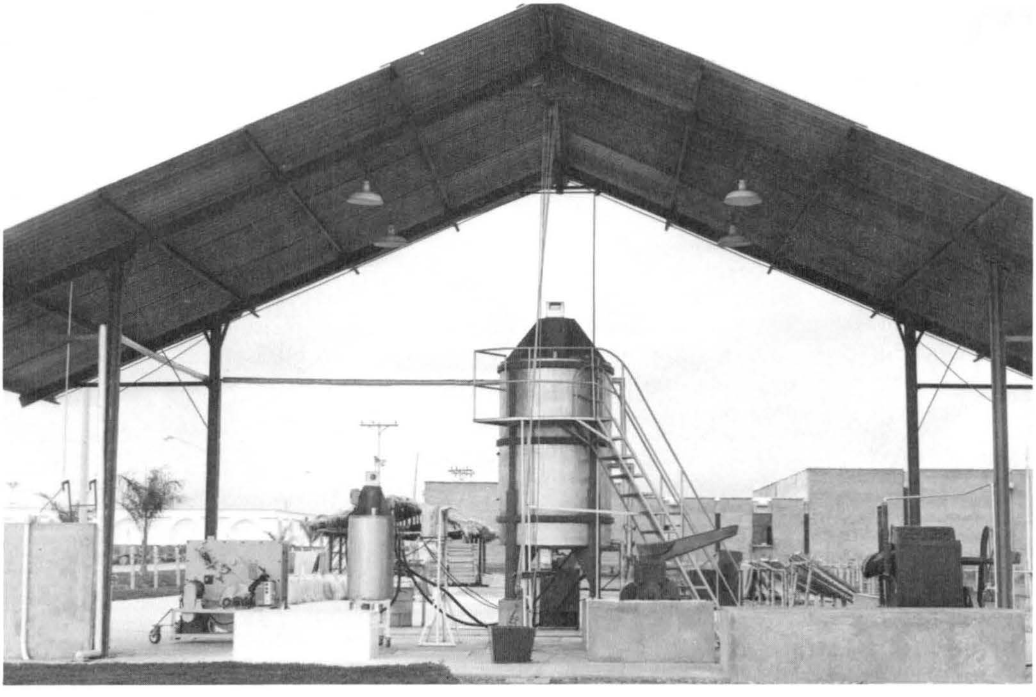
A wide range of projects in Canadian institutions have been supported by the CIDA grant of $750 000 that was provided for basic research in support of the CIAT program. One of the earliest studies dealt with the prospects for utilizing and marketing cassava (IDRC-020e). This study drew attention to the growing world trade in dried cassava used as an alternate source of energy to feed grains in compound animal feedstuffs. This work indicated that the international trade in dried cassava chips or pellets, which was worth about $100 million in 1973, was likely to multiply five- or sixfold by the end of the decade. In fact, by 1978, the value of this trade had exceeded the $600 million mark. This study also indicated that there was a considerable potential for using cassava as an animal feed in developing countries as well as in the EEC countries that purchase most of the cassava currently handled in the international feed trade.

A project at the University of Guelph entailed growing cassava in large growth chambers to study its growth physiology. Further work at Guelph dealt with establishing the symptoms of micronutrient deficiencies and excesses in cassava grown hydroponically in pots with artificial soil. This work was part of a cooperative study with CIAT and the University of Queensland in Australia that resulted in a publication with colour photographs illustrating mineral deficiency and toxicity symptoms in the cassava plant (CIAT publication GE-16).

Work on toxicity has also taken place at Guelph to study the fundamental nature of the toxicity associated with the cyanogen radical in cassava. This work was associated with a workshop and a publication on this theme (IDRC-010e).

Another project, at the University of Guelph, is the largest one in the Canadian component of the cassava program. This project was drawn up to develop a protein-rich animal feed by the conversion of cassava starch and inorganic nitrogen into microbial protein. The project has involved collaborative action between the microbiology, nutrition, animal science, agricultural engineering, and veterinary pathology departments of the University and has involved several graduate students, mainly from tropical areas, in its research activities. The project's specifications called for the development of a microbiological process with a minimum risk of toxicity to the livestock consuming the product and to the personnel involved in its production. A variety of fungal organisms have been studied, and from three of them promising results have been obtained under systems that are transferable to developing countries.

The project is currently at the stage where a 3000 litre pilot scale fermentor has been constructed and tested at Guelph prior to being shipped to CIAT. This fermentor is working at present with a non-sporulating mutant of the filamentous fungus *Aspergillus niger* that only grows under very acid conditions and at a temperature in excess of 40°C. Animal feeding trials with the products of the fermentor are still at an early stage, but the unit is large enough to provide high protein feed for large experimental trials.



The pilot fermentor at the CIAT swine unit produces microbial protein using cassava roots as the energy source.

Two difficult projects were undertaken at McGill University, Montreal. The first attempted, without success, to identify the causative agent of African cassava mosaic. This problem has defied resolution for many years, but recently it appears to have been solved by a British team working in East Africa. Midway through the program, IDRC sponsored a workshop that brought together the scientists at McGill and those in East Africa and enabled them to interchange views and experiences with scientists working on this problem elsewhere in the world (IDRC-071e). A second project, carried out at McGill University, attempted to classify the large collection of germ plasm at CIAT by analyzing the phenolic composition of different cultivars. It was found that the collection could be grouped into related cultivars using this technique but unfortunately these chemical relationships could not be correlated with economic characteristics such as disease and insect resistance, high yield, or early maturity.

The Prairie Regional Laboratory of the National Research Council at Saskatoon has a particular expertise in tissue-culture techniques. CIDA funded support there to develop methods of meristem and single-cell culture of cassava. The meristem culture approach has made excellent progress, and a technique of propagating cassava plants that appear to be free of cassava mosaic disease has been developed. This may be of particular value for the mosaic-free production of cassava in India and Africa.

IDRC has recently funded a modest follow-up project to determine whether cassava meristematic tissue can be stored at −196°C in liquid nitrogen. If successful, this technique could enable large germ plasm collections to be stored cheaply for long periods, which would be far more economical, secure, and convenient than the present system of growing the whole germ plasm collection continuously in plots. If this method of storage is found to give adequate safeguards against disease transmission, it may also have an important application for the safe transport of germ plasm between countries. At present this movement is severely inhibited by necessary phytosanitary regulations.

The last project to be mentioned in Canada is one at the University of Manitoba that investigated the possibilities of using cassava flour as a partial substitute for wheat flour for bread-making. This process is of interest in tropical nonwheat-growing countries that can use it to economize on imports of wheat flour. The research program was successful, and showed that satisfactory bread could be made from composite flour containing up to 50% of other flours mixed with wheat flour. An important component of the success was due to a mechanical method of developing the dough by repeated sheeting between rollers instead of the normal fermentation process.

Africa

As already mentioned, there is an important program of research on cassava at IITA in Ibadan, Nigeria. This research does not duplicate the program at CIAT because it focuses principally on investigating and overcoming one specific disease, common cassava mosaic, which is widespread in Africa and India but unknown in Latin America and Southeast Asia.

The major emphasis of the program at IITA is on identifying resistance to common cassava mosaic and in endeavouring to combine such resistance with high yield. A very large-scale crossing and screening program is under way and is producing over 100 000 seedlings a year from 1500 families. The most promising single seedlings are then widely tested at different locations within Nigeria and elsewhere in Africa.

The second most important disease of cassava is known as cassava bacterial blight. Until recently, this disease was regarded as being of limited importance in Africa, but serious outbreaks, particularly in Nigeria and Zaire, have suggested that the disease can cause losses equal to or even more severe than those due to mosaic. Although a lot of work on cassava bacterial blight has already been carried out at CIAT, the strains of the organism found in Africa and the methods of cultivation used in that continent are such that the CIAT control measures have had to be adapted for use in Africa. To facilitate this and to help map the incidence and importance of the disease on this continent, IDRC has supported a large project dealing with this problem at IITA.

Two IDRC projects involving cassava are based at the University of Ife in Western Nigeria. The first of these examines the potential for the use of cassava in animal rations in West Africa, and lays particular stress on determining the most appropriate local protein sources for supplementing cassava to provide balanced animal rations. This project could be of particular importance if the Nigerian national accelerated food program, strongly supported by IITA, were to lead to significant increases in the production of cassava in Nigeria. The potential for using surplus production as an animal feed is particularly attractive because cassava is an important basic staple that probably has a relatively inelastic market, whereas the supply of animal protein products is limited and the market for these has a very high demand elasticity in the booming Nigerian economy.

The second project at the University of Ife has involved the study of several socioeconomic factors such as income, employment, end-product costs, and marketing, when "gari," the traditional Nigerian food made from processed cassava, is produced in a mechanized, rather than traditional, fashion. Traditional production of gari is a small village-scale activity, but recently a highly capital-intensive, fully-mechanized gari production process has been developed. Between these two extremes there also exists an intermediate technology process. The project at the University is looking at all three processes in terms of their costs and benefits, in both economic and social terms, with a view to assisting the Government to devise long-term policies in this field.

The fermentation process involved in gari production is designed to break down the cyanogenic glucosides whose presence in cassava has already been mentioned. In parts of Africa, where these glucosides are incompletely processed, toxicity problems occur in humans after eating the end products. One of these problems involves a disturbance in iodine metabolism resulting in cretinism in children and goitre in adults. This problem is peculiarly confined to the North of Zaire where it appears to contribute to the presence of a high incidence of goitre in a population of 600 000 people. IDRC has provided support through its Health Sciences Division to the Central African Science Research Institute (IRSAC) in Eastern Zaire and to the University of Brussels in Belgium to investigate the influence of cassava on iodine metabolism in Zaire and also to examine whether iodine can be used prophylactically with success in those areas where cassava consumption is extremely high.

IDRC is supporting two national programs of root crop research in Africa. The first is in the Cameroons where the National Agricultural Research Institute (ONAREST) has recently initiated a program on the introduction, screening, and testing of germ plasm of a range of tropical root crops. A similar project, but with a much sharper focus on cassava, is being supported in Zanzibar, another area where cassava may form as much as half of the energy intake.

Because of the increased interest in cassava during the last decade, a great deal of germ plasm has been moved across national boundaries — sometimes illegally. This appears to have resulted in the introduction to Africa of two pests of cassava originating in Latin America where they appear to be kept under control by natural parasites and predators. The two pests are a species of mealy bug (*Phenococcus manihoti*), which has appeared in Zaire, Congo Brazzaville, Nigeria, and Senegal, and the green spider mite (*Mononychellus tanajoa*) that, after being accidentally introduced into Uganda in 1972, has already spread across humid Africa and now ranges from Zanzibar to the West Coast. Both pests cause particularly severe losses at certain times of year. They are being investigated on an international scale through grants provided by IDRC to the Commonwealth Institute of Biological Control (CIBC). The Institute is searching for natural parasites and predators through a program mounted from its station in Trinidad. Some potentially effective predators were identified early in this program and their value is now being determined at the field level in Africa.

Asia

Although Asia is traditionally regarded as the rice bowl of the world, in certain parts of the continent, cassava rather than rice provides the basic food staple. This is the situation in the South of India where in the states of Kerala and, to a lesser extent, Tamil Nadu, cassava is the main source of carbohydrate. India's national Central Tuber Crop Research Institute (CTCRI), located in Trivandrum not far from the southern tip of India, has the largest national root crop research team of any institute in the world.

CTCRI has focused its activities on breeding disease-resistant high-yielding germ plasm. The Institute has always lacked resources to interchange its experiences and scientists with those at other root crop research institutes and has also had very limited funds for extending the results of its research at the farm level. An IDRC supported program is now enabling CTCRI to develop a plant introduction and international testing unit for introducing and evaluating new germ plasm from CIAT, IITA, and elsewhere. Support is also being given for an operational research unit that is surveying farmers' cultivation practices and also measuring the impact and success of CTCRI practices and materials on farmers' farms. In the area in which this unit is working, many farms are only 0.20 hectares in size with practically half of their land devoted to cassava cultivation. Under such extreme conditions, the margin for error is extremely limited and, given the population and land pressures which exist, successful research could have a very important impact.

Because cassava is an important food staple in Southern India, the market for it is extremely sensitive to variations in supply. For this reason, CTCRI is devoting considerable attention to examining post-harvest problems in the fields of drying, storage, processing, and utilization. It is important to make progress in these fields to help stabilize the market, particularly if CTCRI's research results on higher yields were to gain wide acceptance by the farmers.

The national cassava research programs in both Sri Lanka and Malaysia are also being supported by IDRC. In Sri Lanka, the project involves the improvement of both cassava and sweet potatoes by scientists at the Central Agricultural Research Institute at Peradeniya. Although Sri Lanka adjoins India, it appears to be particularly fortunate in that both its cassava and sweet potato crops are free from viral diseases so that an improvement program in this country requires particular care with regard to the importation of germ plasm. This is also true in Malaysia where the IDRC project is centred at the Malaysian Agricultural Research and Development Institute (MARDI). In this program, an IDRC adviser provided some guidance for the first four years. During this period, many of the Malaysian scientists underwent extensive training periods at CIAT. In both this project and the one in Sri Lanka, funds have been provided to enable members of the national teams to undertake research while working on the project to qualify for a local MSc degree.

A second project, located at the University of Malaysia, dealt with the use of cassava in animal rations. This project involved the study of techniques for raising the protein content of cassava by microbiological fermentation. It focused on a different fermentation approach to that adopted by Guelph but met with less success. However, during the course of the project some valuable work was undertaken toward identifying the constraints to the use of high levels of cassava in pig and poultry rations.

A related project is under way at Khon Kaen University in Northeast Thailand where particular emphasis has been devoted to relating the chemical composition of processed cassava to its biological value as animal feed. This is a problem of particular importance in Thailand which is by far the world's largest exporter of cassava. In 1978, the export of dried cassava chips and pellets brought in an income of over $600 million and cassava became the country's number one export crop. The volume of exports is such that the product is now competing with some traditional feed energy sources and it appears to be important for Thailand to improve its quality control standards if it is to avoid new tariff barriers currently under discussion.

To support further work in this direction, IDRC is assisting the Asian Institute of Technology (AIT) in Bangkok to study ways of improving both the process of drying cassava chips and the machines used to turn these chips into pellets for more compact transport. Both of the projects in Thailand resulted from the recommendations of a workshop on cassava processing and storage that was held in Thailand in 1974 (IDRC-031e, Thai version available).

The largest producer of cassava in Asia is Indonesia. A national research program on root crops is currently in the process of formation and IDRC has not, to date, supported any activities at the national level. It is supporting a program at the University of Brawijaya in Eastern Java. This program arose from the observation by a small farmer in this region that grafts between cultivated cassava (*Manihot esculenta*) and a closely related plant called Ceara rubber (*Manihot glaziovii*), which is widely used as a shade tree, produce very large roots. The Ceara rubber tree has a very vigorous canopy but very small roots. When it is grafted onto cassava rootstock, it appears that the luxurious foliage causes large amounts of energy to be translocated to the roots and individual plants 18 months old may have up to 100 kilograms of root. The system of grafting, which is generally known after the name of its founder, Mr Mukibat, is widely used by small farmers in Eastern Java and is traditionally practiced as a backyard system of cultivation. Scientists at the University of Brawijaya are investigating as to whether it can be adapted for commercial use to increase farm cassava yields in an area where the crop is not only important as a staple food but is also processed into pellets and starch for export.

Cassava chipping machinery in use in Thailand. IDRC is supporting the development of improved methods of cassava processing.

The final program to be mentioned is in the Philippines where IDRC has been involved in assisting in the development of a national research program. This program arises from the fairly recently created Philippine Council for Agriculture and Resources Research (PCARR) who have constructed a new National Centre for Root Crop Research at the Visayas State College of Agriculture on the island of Leyte in an important root crop growing area. Six cooperating research centres are involved in the national program that includes work on sweet potatoes and aroids as well as cassava. IDRC support to this program involves funds for training overseas as well as for supporting agro-economic surveys and follow-up research.

In view of the distance of the programs in Asia from both IITA and CIAT, IDRC has provided funds for a CIAT staff member to be based in Asia, located at the Southeast Asian Regional Centre for Agriculture (SEARCA) in the Philippines. This coordinator is responsible for assisting the various national research programs in Asia and for identifying people for further training at CIAT, either through the national programs or through CIAT's own training program, and also for assisting these trainees in their own research programs when they return home.

Cropping Systems

One of the largest networks of projects supported by AFNS is the cropping systems network. Although all AFNS projects are closely related to the improvement of the productivity and welfare of small farmers, there are many possible reasons why the farmers may not adopt new technologies: the technology may not be properly adapted to the farmers' conditions; it may not be profitable enough to outweigh the increased risks involved in its use, especially if the farmer lacks the technical knowledge or skill necessary to obtain the full benefits of the innovation; the markets to which he has access may be too limited to allow him to dispose of his increased production at profitable prices; or he may simply not have enough cash to enable him to buy the extra inputs necessary to get the full benefits from the improved technology. In other words, he finds himself caught in the "small farmer's low productivity trap."

In view of the extraordinarily widespread and intractable nature of this problem, IDRC has supported research in many countries that is designed specifically to determine the real constraints limiting small farmers' adoption of new technologies, to identify those technologies or production alternatives that could help to alleviate these constraints, and then introduce and test them on small farms so that the farmers have the opportunity to choose and modify the introduced technologies to suit their own needs.

Latin America

In 1971, the Colombian Agricultural Institute (ICA) decided to restructure its integrated rural development programs on the lines of the program developed in the Puebla project in Mexico. ICA approached IDRC for assistance in developing the methodology and evaluation techniques for the program, and a small team of three specialists was provided as a part of one of the first projects that IDRC supported.

Initially, the objectives of the Caqueza project were the commonly accepted ones in similar projects of that period, setting out to introduce and test high-yielding cultivars of maize, with a package of fertilizers and other agronomic practices that would give considerably increased production. In the course of time, it was found that this approach needed to be modified in the light of the real constraints that were limiting small farmers' production in the mountainous Caqueza area where the project was centred. In particular, it was found that the systems used on small farms in the area all involved complex methods of intercropping several crops. The researchers soon realized that farmers in the area knew how to allocate their resources efficiently within the limitations in which they had to work, and that some of the most important limitations facing the farmers were those of risk and shortage of money. Although corn yields could be increased three times by the use of high-yielding varieties, fertilizers, and pesticides, this involved a sevenfold increase in the cost of purchased inputs, and the risk from production and price variations increased 15-fold. It was also found that there was too much competition in the existing marketing structure, and this created uncertainties in the marketing situation.

Although the improved technology recommended to the farmers could increase farm income by approximately four times, it was found that the adoption rate by the farmers was very low because of the constraints already mentioned. Before the farmers could be expected to adopt the improved technologies, it was necessary to modify the objectives of the project to identify and reduce the real constraints that were limiting farmer production. Therefore a corn production plan was organized under which a cooperative supplied the inputs of seed, fertilizers, and insecticides to the farmer on credit, in return for which the farmer contracted to share equally with the cooperative any yield in excess of 800 kg/ha. A marketing system was also organized.

In this way, the risks, the cash requirements, and the marketing problems were greatly reduced. As a result the rate of adoption by the farmers was increased, and the return to the farmer and to the cooperative was also high.

The project showed that the search for alternative production systems should go further than simply developing a package that maximizes yield, or even profits, per hectare. It should also include an analysis of socioeconomic factors such as risk, input costs, and labour requirements of the new technologies in comparison with the traditional system.

Although the area and the number of farmers directly affected by the Caqueza project were comparatively limited, the philosophy and methodology developed by ICA in this and other projects, and the many ICA staff trained in these methods of research, contributed to a reorientation of the approach of the whole Colombian Agricultural Research and Extension Service, making it more farmer-centred, and integrating, to a better extent, research and extension activities. As a result, integrated rural development programs have been developed in all parts of Colombia in accordance with this new philosophy.

The Caqueza project and other similar programs aroused a great deal of interest within IDRC and in other organizations as the outlined approach to research and development seemed to offer some promise of breaking through the small farmer poverty trap and making real progress in rural development.

More recently, two small cropping systems type projects have been developed in Honduras and Nicaragua in collaboration with the Centre for Tropical Agricultural Research and Training (CATIE), an organization based in Costa Rica that undertakes research in collaboration with countries in the Central American region.

The two projects are concentrating first on expanding the information base on cropping systems in the chosen areas in the two countries. Detailed studies are being carried out on farmers' production systems, management practices, resources of land, labour, and capital, and on agroclimatic and land-use factors. Selected farmers are cooperating in continuous data collection for a period of at least one year. These in-depth studies include labour use, input and output data, marketing information, credit availability, and other information. They provide the basic information with which improved cropping systems can be devised and tested, first on experimental plots, and then on farmers' fields.

As CATIE already has considerable experience with such cropping systems research in the region, the results of successful work in similar agroclimatic conditions elsewhere will be introduced and tested in the selected areas. Because maize, beans, sorghum, and rice are important in both countries, the experiments will concentrate on improved packages of practices designed for these crops, both in pure stand and intercropped. Throughout the experiments, the farmers will be fully involved in the process of defining and evaluating the proposed improvements and changes in their traditional cropping systems.

A different type of cropping systems project is being supported with the Windward Islands Banana Growers' Association (WINBAN) based in St. Lucia, West Indies.

Nutrition surveys have suggested that as many as 70% to 80% of the population of some of the West Indian islands have inadequate food consumption patterns, and there are considerable food imports into the islands. Bananas are the main export crop from the Windward Islands, and over 70% of the growers produce less than 5 tonnes of bananas a year on small farms below 10 hectares in size. Nearly all the bananas grown on small farms are intercropped with a wide variety of food crops. These include cocoyams, dasheen, eddo, tania, cassava, maize, pigeon peas, and others. Various types of plantain and fruit trees are also often mixed with the bananas.

Although WINBAN has carried out research on the practices required to increase commercial banana production, little is known about the interactions between the bananas and the food crops with which they are associated. Therefore, a survey of existing cropping patterns on the islands is being carried out to define their parameters and to identify the main constraints to greater production of both bananas and food crops. On the basis of this information, improved production practices are being designed and tested with full farmer participation.

A potentially valuable supporting program for the cropping systems and crop improvement work is being carried out by a soil scientist from the International Fertilizer Development Centre (IFDC) working at CIAT in Colombia. This IDRC-supported program is working on the

An example of the successful intercropping of soybeans and maize at CATIE in Costa Rica.

efficient utilization of phosphorus by tropical crops. Approximately one-half of the potentially arable land in the tropics is strongly acid and extremely deficient in phosphorus. Many small farmers in tropical countries do not use fertilizers, often because they cannot afford the rising costs of imported materials.

Many developing countries have their own supplies of phosphate rock, but these have often not been exploited because the phosphate is not thought to be readily available to crops. The IFDC program aims to characterize the phosphate rock from several developing countries, and to carry out laboratory and greenhouse trials in the USA, and field experiments in Colombia to determine the most effective materials and methods for use on different tropical soils.

Africa

The ecological balance in the Sahelian countries was particularly affected by the drought during the late 1960s and early 1970s, and by increasing numbers of people and livestock. IDRC is supporting the Mali Government in a project designed to focus on the weaknesses in the existing farming system in a limited area in the south of that country. The project will start with a baseline land-use and economic survey of a fairly large number of farms, from which a limited sample will be selected for very detailed farm management investigations. As in the Caqueza project, it is hoped that these studies will point out the priority areas for improvements in the farming systems. Improved technologies, production practices, and marketing and credit arrangements for both crops and livestock will then be introduced and tested with the full involvement of the farmers.

A smaller project with the Université du Bénin in Togo is supporting research on cropping systems to be carried out by five staff members of the Faculty of Agriculture. Initially, the work will be concerned with the investigation of a range of improved production practices, both on the university farm and on the farms of local farmers, that may be introduced to help solve problems faced by the farmers. After thorough testing on the experimental farm, the practices will be further tested on additional small farms in the vicinity of the University. This project is also designed to encourage the involvement of young Togolese staff members in the Faculty of Agriculture in applied field research, and to enable them to partake in short training courses in centres such as the International Institute of Tropical Agriculture (IITA) in neighbouring Nigeria. (Another project on the important plantain crop and related cropping systems is being supported in the Cameroon.)

IDRC is also supporting the West African Rice Development Association (WARDA) in research on irrigated rice and associated cropping systems at Richard Toll/Fanaye on the Senegal River in Northern Senegal.

Rice consumption in West Africa has recently been increasing much faster than production, necessitating imports to a value of nearly $240 million a year. In 1970, 14 West African countries, both francophone and anglophone, set up WARDA to increase rice production in the region. To assist WARDA in defining its program of work, IDRC retained the services of the former Director-General of the International Rice Research Institute (IRRI) as a consultant to the association. In view of the enormous untapped potential of the two great rivers of West Africa, the Senegal and the Niger, for irrigation, one of the consultant's recommendations was that IDRC should support WARDA in a research project to explore the possibility of assisting the transfer of the high-yielding rice varieties and associated technology developed in Southeast Asia, to West Africa.

As the high-yielding rice varieties require good water management to realize their full potential, an important aspect of the project is the investigation of improved methods of water management in the West African environment. Emphasis will also be placed on testing multiple cropping systems, drawing from experience at IRRI and in the IDRC-sponsored multiple cropping projects in Southeast Asia. Two or even three successive crops of rice will be tried, and alternative crops for the cooler winter season will also be tested under irrigation. Economic studies will be carried out on the various irrigated rice cropping systems already practiced in the region, and the results of the research at Richard Toll will be tested on small farms in the area.

In East Africa, a small project is being undertaken by the University of Nairobi, Kenya on improved crop rotations and cropping systems for the heavily populated highland areas of Eastern Africa. Increasing population pressure is leading to the breakdown of the traditional shifting cultivation system in many parts of the tropics. This is particularly true in some of the highland areas, such as those around Nairobi. Farmers in these areas are being forced to adopt more settled farming systems, often involving almost continuous cultivation of the land. These systems are leading to widespread soil exhaustion and erosion in many areas, particularly where rainfall intensities are high, slopes are steep, and the soils are relatively infertile. Also, there are often serious problems with soil-born pests and diseases, and with weed infestation. The crops being tested are maize, wheat, Irish potatoes, sweet potatoes, field beans, soybeans, linseed, and sunflower. All possible sequences are being compared, and their interactions with the soil are being monitored. The results of the project should be useful as a basis on which improved cropping systems can be developed.

Middle East

In the Middle East, the semi-arid Mediterranean climate with the characteristically dry summer and winter rain presents food production problems unique to the region. Many of these countries are net food importers because the productivity of the traditional farming systems is low. In many areas, the systems are based on growing a crop of wheat or barley every other year, and leaving the land fallow in the alternate years. The ubiquitous herds of sheep and goats often graze the fallow land and the wheat or barley stubble, but crop yields are generally low and many of the farmers are poor.

IDRC has agreed to support part of the development of the new pasture legume improvement program for the International Centre for Agricultural Research in the Dry Areas (ICARDA). In time, this should make a major contribution to the improvement of the farming systems of the region.

In addition, the Syrian Government has requested IDRC support for a crop intensification project. It is estimated that more than 1 million hectares of good land in the humid and subhumid zones of Syria are left idle under fallow every year. Crop yields are also extremely low, and there are some serious problems with weed infestation, overgrazing, and soil erosion. Some of the marginal rangelands are gradually being lost to desert.

The Government plans an ambitious program to eliminate fallowing and to replace it by a more productive crop and animal production system. Using a rotational system, in which wheat is grown following lentils, yields were in some cases greater but never less than wheat grown after fallow.

Some annual pasture legumes (mainly *Medicago* spp.) indigenous to the Mediterranean area have been successfully transferred to South Australia, which has a very similar climate, and have been improved there and have greatly increased both crop and pasture production. The improved varieties from Australia will be compared with legumes collected in the Middle East to determine their effectiveness in improving soil fertility and animal production in Syria. A considerable amount of work is needed on the agronomic practices and particularly the fertilizers required to develop suitable farming systems for the various ecological zones in the country. Then the proposed farming systems must be tested and adapted to the farmers' actual conditions throughout the country. There will also be a substantial training component in this project to train Syrian scientists in farming systems research.

Asia

Since 1972, a major focus of the cropping systems program supported by IDRC has developed in close association with the IRRI Cropping Systems Network in South and Southeast Asia. In the 1960s, the new short-strawed, fertilizer-responsive, and high-yielding rice varieties bred at IRRI had contributed to large increases in production throughout the irrigated rice-growing areas in South and Southeast Asia. By the early 1970s, it was apparent that small farmers growing mostly rain-fed lowland rice had not benefited from this breakthrough and that there was an urgent need to intensify the production of all crops, especially rice, under rain-fed conditions in the most heavily populated areas.

This could be done in several different ways. One promising alternative seemed to be to grow two successive rice crops by direct seeding a quick-maturing rice crop at the beginning of the rainy season, and transplanting a second crop as soon as the first crop was harvested. Using these methods, yields of 7–10 tonnes of paddy per hectare per year have been obtained, compared to the usual 2–4 tonnes average normally achieved by farmers. In addition, IRRI has emphasized the intensification of production by growing several crops other than rice, either in rotation with rice, or intercropped with rice.

Like the Caqueza project, with which it has staffing links, the IRRI program has emphasized on-farm research from the beginning. A methodology combining agronomic and economic studies has been gradually developed involving the description of the environment, both agroclimatic and socioeconomic; study of the interactions between the environment and technologies; development and evaluation of new component technology; and design and testing of improved cropping patterns.

In view of the "location specific" nature of much of the research, IRRI has established a strong network of cooperating programs in rice-producing countries of Southeast Asia. An important function of this network approach has been a large-scale training program for cropping systems researchers from all the cooperating programs, mainly at IRRI. A cropping systems working group has also been established that holds regular meetings in each country in turn, to compare experiences and plan future programs. In this way, IRRI has succeeded in introducing a virtually new philosophy into the research programs of cooperating countries, and has provided the beginnings of a trained staff and a methodology for undertaking farm-based research on cropping systems. The improved germ plasm, and other technological components, which IRRI also provides from its other programs, make a substantial contribution to the improved cropping systems that must be developed and adapted by national institutions for each set of agroclimatic and socioeconomic conditions.

An early parallel effort, and later component of the IRRI Cropping Systems Network, was the multiple cropping program with the University of the Philippines at Los Banos (UPLB). This program concentrated on the growing of vegetable crops following rice under specific conditions. A great deal of attention was paid to the effective organization of supporting services to the farmer research program. Work began in six villages close to Los Banos in 1972, and this was expanded to 18 more villages in January 1974. Farmers in these villages plant a wide variety of crops in rotation with rice or intercropped with coconut trees including watermelon, cucumber, mung bean, tomato, eggplant, cowpea, gourd, maize, peanut, sweet potato, yam, ginger, arrowroot, and others.

Initially, one technician was provided for each village to carry out extension work among the farmers, and the farmers were encouraged to form farmers' organizations to organize the supply of inputs, market the produce, and provide credit. Where these organizations provided a needed service to the farmers it was found that they became viable institutions continuing after the technician was withdrawn. One technician was required for each village, but when a single technician was provided for several villages few results were achieved unless the technician concentrated his efforts on only one or at most two close-by villages.

In general, the farmers who adopted multiple cropping increased their farm incomes by two to three times, and there has been a corresponding increase in the amount and variety of food consumed by the farm families. The improvement in the nutritional level of the families is clearly reflected in the increases in both the weight and height of preschool children.

A project to screen upland crops for cropping systems programs was started at UPLB at the request of IRRI. Because UPLB already had advanced breeding programs using many of the crops that appeared to be suitable for the cropping systems work, it was a convenient place to screen varieties considered for inclusion in cropping patterns that would see them grown either before or after rice, or intercropped with it.

Germ plasm was collected from many sources, including the international centres, and the following number of lines obtained were grown at UPLB: 6017 tomato, 572 eggplant, 1221 soybean, 2105 mung bean, 282 peanut, 364 cowpea, 2100 corn, 599 sorghum, and 716 sweet potato. Most of this collection has now been screened for suitability for multiple cropping systems. Selections that are particularly suitable are channeled through the multiple cropping working group to the various collaborating country programs for testing under local conditions. Those varieties that are useful and superior to local varieties have been incorporated into national cropping systems research and development programs.

Another IDRC-supported component of the Cropping Systems Network is a joint project with IRRI at the Bangladesh Rice Research Institute (BRRI). Although the staple food in the country is rice, many other crops are grown, and there appear to be good prospects for intensifying local cropping systems by the introduction of higher-yielding varieties, or different crops, with appropriate agronomic practices. Experimental results showed that rice yields could be increased as much as 40% in this way in one area, and that where winter irrigation is available, wheat can be grown when much of the land is traditionally left uncropped.

Unfortunately, low crop prices due to the policy of inexpensive food for the cities, and massive quantities of imported food aid, create little incentive for the farmers to increase their production. However, some farmers have started growing wheat successfully, and the opportunities for expanding production appear to be good. There are also good prospects of increasing the production of various grain legumes, root crops, and vegetables. Bangladesh is extremely short of trained staff to undertake the necessary research program, but staff from BRRI and other Bangladesh research institutes are being trained at different levels to work in an expanded national cropping systems program currently being developed.

In Sri Lanka, IDRC is providing support to the Ministry of Agriculture for a cropping systems project in the dry and intermediate zones of the country. Rainfall is very uncertain in the drier areas, and small reservoirs, or tanks, have been used by farmers in these areas since the first century A.D., but even with supplementary irrigation from these tanks, the probability of obtaining a single crop of rice per year is barely 75%. Yet there is an urgent need to intensify rice production and to expand the production of other food crops in the country.

In addition to rice, the crops being tested include sorghum, maize, sweet potatoes, cassava, black grams, cowpeas, soybeans, groundnuts, and vegetable crops including okra, onions, chillies, eggplants, and tomatoes. Because of the wide variety of agroclimatic conditions in Sri Lanka, different solutions have to be worked out for the different agroecological areas. However, progress is being made and the farmers are already showing considerable interest in some of the improved practices being tested.

Thailand is an important rice-producing country and a limited amount of research on rice-based cropping systems has been carried out there for several years. In 1976, the Ministry of Agriculture requested support for a large cropping systems project in four different regions of the country where previously little research of this type had been done.

IDRC provided an experienced adviser to assist the Thai scientists working in this program, and Kasetsart University will assist in training scientists and technicians. IRRI staff periodically review the operations and results of the project and take part in annual workshops with all those working in the project. About 11 Thai research workers have received training at IRRI, and several of them will work toward MSc degrees at UPLB.

IDRC is also cooperating with IRRI to support an ambitious Indonesian Government research program designed to intensify cropping systems in Java and Sumatra.

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Latin America and Canada						
72–0073 74–0132	Mexico	Sorghum (CIMMYT)	Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) Londres 40 Mexico 6, DF	I II	1972–75 1975–77	70 170 124 700
76–0134 78–0092	Mexico	Cold-Tolerant Sorghum (ICRISAT)	Dr Vartan Guiragossian Sorghum Breeder International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Apartado Postal 6–641 Mexico 6, DF	I II	1976–78 1979–80	198 600 122 500
78–0046	Costa Rica	Drought-Resistant Crops (CATIE)	Dr Pedro Onoro Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) Turrialba, Costa Rica	I	1978–81	180 000
72–0101 74–0107	Canada	Drought Resistance	M J.-Marc Trudel Chairman, Plant Science Department Laval University Québec, Canada G1K 7P4	I II	1973–75 1975–77	76 800 154 900

(Table continued)

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IDRC-Supported Sorghum/Millet Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
73–0129	Canada	Drought Tolerance	Dr G.M. Simpson Director Crop Development Research Centre University of Saskatchewan Saskatoon, Saskatchewan Canada S7N 0W0	I	1974–80	672 000
75–0019	Canada	Sorghum × Maize Hybrid (PRL)	Dr Burt Craig Prairie Regional Laboratory (PRL) National Research Council 110 Gymnasium Road University Campus Saskatoon, Saskatchewan Canada S7N 0W9	I	1975–78	104 500
Africa						
72–0011 75–0088	Senegal	Sorghum Breeding, Intercropping and Grain Preservation	M Mahawa Mbodj Directeur Centre National de Recherches Agronomiques (CNRA) Bambey, Sénégal	I II	1972–76 1976–78	957 600 380 000

(*Table continued*)

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72–0051 75–0116	East Africa	Sorghum Improvement	Mr Vincent Makumbi Acting Principal Research Officer in Charge Sorghum and Millet Unit P.O. Box Soroti Uganda	I II	1972–75 1975–77	76 000 132 500
72–0054 75–0110	Uganda	Sorghum/Finger Millet/ Pigeon Peas	Dean of Agriculture Makerere University P.O. Box 7062 Kampala, Uganda	I II	1972–76 1976–78	195 050 171 500
72–0025 74–0087	Tanzania	Intercropping	Prof A.P. Uriyo Acting Dean Faculty of Agriculture, Forestry and Veterinary Sciences University of Dar es Salaam P.O. Box 643 Morogoro, Tanzania	I II	1972–75 1975–79	120 570 597 000
75–0037	Rwanda	Sorghum/Triticale/ Oilseeds	Le Directeur Général Institut des Sciences Agronomiques du Rwanda (ISAR) Station de Rubona B.P. 138 Butare, République Rwandaise	I	1976–79	197 000

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(Table continued)

IDRC-Supported Sorghum/Millet Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
72–0095 74–0023	Ethiopia	Sorghum Improvement	Dr Brhane Gebrekidan Ethiopian Sorghum Improvement Project (ESIP) P.O. Box 414 Nazreth, Ethiopia	I II	1973–75 1975–78	195 300 560 000
76–0103	Kenya	Insect Resistance (ICIPE)	Prof T.R. Odhiambo Director The International Centre of Insect Physiology and Ecology (ICIPE) P.O. Box 30772 Nairobi, Kenya	I	1977–79	322 600
78–0112	Swaziland	Intercropping	Prof W. Godfrey Sam-Aggrey Head Crop Production University College of Swaziland P.O. Luyengo Swaziland	I	1979–82	143 400
Middle East						
73–0010 75–0031	Lebanon	Sorghum/Millet/ Legumes (ALAD)	Director The Arid Lands Agricultural Development Program (ALAD) P.O. Box 2379 Beirut, Lebanon	I II	1973–75 1975–76	680 300 600 000

(Table continued)

(*Table continued*)

Asia						
75–0072	India	Millets	Dr G. Harinarayana All India Coordinated Millet Improvement Project Mahatmaphula, Krishi Vidyapeeth, Rahuri, 413722 India	I	1978–80	530 000
74–0058	Thailand	Semi-Arid Crops	Head Department of Plant Science Faculty of Agriculture Khon Kaen University Khon Kaen, Thailand	I	1975–80	311 000
73–0041	Papua New Guinea	Sorghum/Maize	Dean Department of Agriculture University of Papua New Guinea Box 4820, University Post Office Papua New Guinea	I	1975–78	140 200
Europe						
75–0043 76–0102	England	Polyphenols (Sheffield)	Dr Eddi Haslam University of Sheffield Western Bank Sheffield S10 27N England	I II	1975–77 1978–79	25 100 24 900

(*Table continued*)

(*Table concluded.*)

IDRC-Supported Sorghum/Millet Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Parasitic Weeds						
73–0015 75–0065 76–0101	England	*Striga* (Sussex)	Prof A.W. Johnson, FRS School of Molecular Sciences University of Sussex Falmer Brighton BN1 9QJ England	I II III	1973–75 1975–76 1976–78	47 700 107 500 84 100
78–0085	England	*Orobanche/Striga* (Sussex)	Prof A.W. Johnson, FRS School of Molecular Sciences University of Sussex Falmer Brighton BN1 9QJ England	I	1979–81	88 600
77–0041	Sudan	*Striga*	Prof Ali E. Kambal Department of Agricultural Botany Faculty of Agriculture University of Khartoum Shambat, Sudan	I	1978–80	251 200
78–0006	Upper Volta	*Striga*	Dr Pattanayak International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) Sorghum/Striga Research Unit Kamboinse Research Station (Ouagadougou), Upper Volta	I	1979–81	397 900

IDRC-Supported Triticale Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Canada and Latin America						
*C-71-8102-00	Canada	Triticale Research (Manitoba)	Dean Faculty of Agriculture University of Manitoba Winnipeg, Manitoba Canada R3T 2N2	I	1971-77	575 000
*C-71-8103-01	Canada	Kernel Shrivelling (Manitoba)	Dean Faculty of Agriculture University of Manitoba Winnipeg, Manitoba Canada R3T 2N2	I	1972-77	50 950
*C-71-8103-03	Canada	Spring Rye (Manitoba)	Dean Faculty of Agriculture University of Manitoba Winnipeg, Manitoba Canada R3T 2N2	I	1974-77	64 000
*C-71-8103-04	Canada	Winter Triticale (Guelph)	Head Department of Crop Science University of Guelph Guelph, Ontario Canada N1G 2W1	I	1974-77	133 000

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IDRC-Supported Triticale Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
74–0149	Canada	Triticale (Manitoba)	Dr Ed Larter Professor Faculty of Agriculture University of Manitoba Winnipeg, Manitoba Canada R3T 2N2	I	1977–78	121 800
74–0026 76–0148 77–0081	Canada	Winter Triticale (Guelph)	Dr E. Reinbergs Department of Crop Science University of Guelph Guelph, Ontario Canada N1G 2W1	I II III	1974–77 1977–78 1978–80	15 000 93 800 210 200
*C–71–8101	Mexico	Triticale Research	Director Centro Internacional de Mejoramiento de Maiz y Trigo (CIMMYT) Londres 40 Mexico 6, DF	I	1971–76	2 500 000
73–0012 76–0088	Chile	Triticale	Dr Patricio C. Parodi Head Department of Plant Science Universidad Catolica de Chile Casilla 114–D Santiago, Chile	I II	1974–77 1977–80	91 000 207 200

(*Table continued*)

(*Table concluded.*)

Africa						
72-0024 76-0052	Ethiopia	Triticale Outreach	General Manager Institute of Agricultural Research (IAR) P.O. Box 2003 Addis Ababa, Ethiopia	I II	1972–76 1976–79	97 290 176 200
73-0050	Kenya	Triticale	Senior Wheat Research Officer Department of Agriculture Ministry of Agriculture Plant Breeding Station Njoro, Kenya	I	1974–77	87 000
Middle East						
74-0142	Lebanon	Triticale	Head Department of Agriculture American University of Beirut Beirut, Lebanon	I	1975–78	107 000
Asia						
74-0004	India	Triticale	Director of Research G.B. Pant University of Agriculture and Technology Pantnager, Distt. Nainital Uttar Pradesh State, India	I	1974–78	241 785

*CIDA-funded and IDRC-managed projects.

IDRC-Supported Food Legume and Oilseed Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Latin America						
71–0078 74–0160	Trinidad	Grain Legumes	Dr John Spence Department of Biological Sciences University of the West Indies St. Augustine, Trinidad, W.I.	I II	1972–75 1975–77	186 425 309 500
76–0078	Bolivia	Quinoa	Director Instituto Boliviano Tecnologico Agricola (IBTA) La Paz, Bolivia	I	1976–80	315 500
78–0107	Colombia	Quinoa Introduction	Wenceslao Vargas Director Instituto de Ciencias y Tecnologia de Alimentos Universidad Nacional AA. 14490 Bogota, Colombia	I	1979–81	14 800
Africa						
74–0128–02	Upper Volta	Food Legumes (IITA)	Director-General International Institute of Tropical Agriculture (IITA) Oyo Road P.M.B. 5320 Ibadan, Nigeria	I	1977–79	177 100

(Table continued)

(*Table continued*)

74–0128–03	Upper Volta	Food Legumes	M. J. Kabore Directeur des Services Agricoles Ministère du Développement Rural Ouagadougou, Haute-Volta	I	1977–79	82 000
77–0092	Niger	Food Legumes	Directeur Centre de Recherches Agronomiques du Niger (CENRAN) Tarna, B.P. 240 Maradi, Niger	I	1979–82	153 000
78–0040	Mali	Food Legumes	Dr N'golo Traore Institut d'Economie Rurale Bamako, Mali	I	1979–82	212 000
77–0102	Sierra Leone	Food Legumes	Dr W.E. Taylor Dean, Faculty of Agriculture Njala University College University of Sierra Leone Private Mail Bag Freetown, Sierra Leone	I	1978–81	126 000
75–0131	Kenya	Pigeon Peas	Dr D. Ngugi Department of Crop Science University of Nairobi P.O. Box 30197 Nairobi, Kenya	I	1976–78	103 000
Middle East and North Africa						
73–0010 75–0031	Lebanon	Sorghum/Millet/ Legumes (ALAD)	Director The Arid Lands Agricultural Development Program (ALAD) P.O. Box 2379 Beirut, Lebanon	I II	1973–75 1975–76	680 300 600 000

(*Table continued*)

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
74–0138	Syria	Dryland Agriculture (ICARDA)	Executive Director International Centre for Agricultural Research in the Dry Areas (ICARDA) P.O. Box 5466 Aleppo, Syria	I	1976–77	550 000
74–0119 78–0041	Syria	*Orobanche* Control (ICARDA)	Dr F. Basler Weed Control Scientist International Centre for Agricultural Research in the Dry Areas (ICARDA) P.O. Box 5466 Aleppo, Syria	I II	1974–78 1978–81	48 000 106 000
77–0101	Syria	Grain Legumes (ICARDA)	Dr G.C. Hawtin International Centre for Agricultural Research in the Dry Areas (ICARDA) P.O. Box 5466 Aleppo, Syria	I	1978–80	942 850
73–0033	Algeria	Triticale, Legumes	M N. Kadra Institut de Développement des Grandes Cultures B.P. 16, El Harrach Alger, Algérie	I	1974–79	182 800
78–0043	Algeria	Grain Legumes	M N. Kadra Institut de Développement des Grandes Cultures B.P. 16, El Harrach Alger, Algérie	II	1979–81	197 300

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77–0073	Egypt	Food Legume Improvement	Dr Ali Abdel-Aziz Field Crops Research Institute Agricultural Research Centre Giza, Cairo Egypt	I	1977–80	243 800
78–0044	Egypt	Oilseeds	Dr Mostafa Serry Director Oil Crops Section Field Crops Research Institute Agricultural Research Centre Giza, Cairo Egypt	I	1978–81	223 000
75–0112	Egypt	*Orobanche* Control	Dr O. Al-Menoufi Principal Investigator Faculty of Agriculture University of Alexandria Shatby, Alexandria Egypt	I	1977–80	45 000
77–0060	Sudan	Food Legume Improvement	Dr Farouk A. Saleh Legume Breeder Hudeiba Research Station Ed Damer, Sudan	I	1977–80	210 200
73–0143	Israel	Sesame	Prof Amram Ashri The Levi Eshkol School of Agriculture Rehovot Campus P.O. Box 12 Rehovot, Israel	I	1975–78	69 700

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IDRC-Supported Food Legume and Oilseed Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
78–0048	Turkey	Food Legumes	Mr Attila Altinay Head of Breeding and Production Department General Directorate of Agricultural Research Ministry of Food, Agriculture and Animal Husbandry P.O. Box 226 Ankara, Turkey	I	1979-82	255 500
Asia						
73–0013 74–0161	India	Grain Legumes (ICRISAT)	Director International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) 1–11–256 Begumpet Hyderabad 500 016, A.P. India	I II	1973–75 1975–77	496 000 998 000
75–0098	India	Sesame	Prof S. Kamalanathan Head, Department of Botany Tamil Nadu University Coimbatore, India	I	1978–81	167 000
75–0032	India	Rapeseed	Dr R.P. Paliwal Dean College of Agriculture G.B. Pant University of Agriculture and Technology Pantnagar, Distt. Nainital Uttar Pradesh State, India	I	1978–81	126 000

(Table continued)

(*Table concluded.*)

75–0097	India	Safflower	Dr D.P. Motiramani Director Research Services Jawaharlal Nehru Krishi Veshwa-Vidhyalaya Jabalpur, Madhya Pradesh India	I	1978–81	100 800
75–0114	India	Mustard	Dr Dharampal Singh Director of Research Haryana Agricultural University Hissar, Haryana India	I	1978–81	270 000
76–0132	Sri Lanka	Food Grain Improvement	Senior Research Officer Agricultural Research Station Maha Illuppallama, Sri Lanka	I	1976–79	165 000
77–0048	Bangladesh	Grain Legumes	Dr Kazi M. Badruddoza Director Bangladesh Agricultural Research Institute (BARI) 87 Pioneer Road Kakrail, Dacca 2 Bangladesh	I	1978–80	220 000

IDRC-Supported Root Crop Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Latin America and Canada						
71-0081 72-0125	Colombia	Cassava Outreach	Director General Centro Internacional de Agricultura Tropical (CIAT) Apartado Aéreo 67-13 Cali, Colombia	I II	1971-72 1973-76	82 000 195 000
74-0162	Colombia	Cassava Cooperative Research (Latin America)	Director General Centro Internacional de Agricultura Tropical (CIAT) Apartado Aéreo 67-13 Cali, Colombia	I	1976-80	379 000
73-0146	Brazil	Cassava	Director General Centro Internacional de Agricultura Tropical (CIAT) Apartado Aéreo 67-13 Cali, Colombia	I	1974	28 000
76-0038	Brazil	Cassava Germ Plasm	Mr N.M.A. Nassar Departamento de Fitotecnia Universidade Federal de Paraiba 58397 Areia Paraiba, Brazil	I	1977-80	46 500
71-0079 75-0001	Trinidad	Root Crops (Caribbean)	Dr Lawrence A. Wilson Department of Soil Science University of the West Indies St. Augustine, Trinidad, W.I.	I II	1972-75 1976-77	161 430 156 100

(Table continued)

(*Table continued*)

76–0160	Trinidad	Cassava Mealy Bug	Commonwealth Institute of Biological Control (CIBC) Gordon Street Curepe, Trinidad, W.I.	I	1977–80	56 300
73–0136 75–0026	Trinidad	Cassava Mites	Commonwealth Institute of Biological Control (CIBC) Gordon Street Curepe, Trinidad, W.I.	I II	1974–76 1976–79	13 600 48 000
74–0002	Peru	Cassava	Centro Internacional de Agricultura Tropical (CIAT) Apartado, Aéreo 67–13 Cali, Colombia	I	1974–76	35 000
74–0153	Ecuador	Cassava	Centro Internacional de Agricultura Tropical (CIAT) Apartado Aéreo 67–13 Cali, Colombia	I	1975–76	5578
75–0094 76–0120 78–0130	Canada	Cassava Microbiology (Guelph)	Dr K.F. Gregory Department of Microbiology University of Guelph Guelph, Ontario Canada N1G 2W1	I II III	1976–77 1977–79 1979–80	7500 102 000 49 900
78-0024	Canada	Cassava Germ Plasm (PRL)	Dr B. Craig Director Prairie Regional Laboratory (PRL) National Research Council 110 Gymnasium Road University Campus Saskatoon, Saskatchewan Canada S7N 0W9	I	1978–79	25 000

(*Table continued*)

IDRC-Supported Root Crop Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
*C-8202-10	Canada	Cassava Mosaic Study (McGill)	Dean of Agriculture The Macdonald Campus of McGill University Ste-Anne-de-Bellevue, Québec Canada H0A 1C0	I	1973-77	94 234
Africa						
74-0047 77-0034	Nigeria	Cassava	Dr A.A. Adegbola Head Department of Animal Science University of Ife Ile-Ife, Nigeria	I II	1975-77 1978-80	114 100 169 100
73-0123	Nigeria	Bacterial Blight	Director General International Institute of Tropical Agriculture (IITA) Oyo Road P.M.B. 5320 Ibadan, Nigeria	I	1974-77	180 000
75-0041-02	Cameroon	Root Crops (IITA)	Director General International Institute of Tropical Agriculture (IITA) Oyo Road P.M.B. 5320 Ibadan, Nigeria	I	1977-80	210 700
75-0041-03	Cameroon	Root Crops (ONAREST)	Le Directeur Général Organisation Nationale de la Recherche Scientifique et Technique du Cameroun (ONAREST) B.P. 1457 Yaoundé, Cameroun	I	1977-80	111 500

(Table continued)

76–0105	Zanzibar	Cassava	Director of Crop Development Ministry of Agriculture and Lands Zanzibar, Tanzania	I	1977–80	54 500
Asia						
74–0056	India	Cassava	Dr N.P. Hrishi Director Central Tuber Crop Research Institute (CTCRI) Trivandrum, 69017 Kerala, India	I	1976–79	361 000
77–0049	Sri Lanka	Root Crops	Dr C.R. Pannabokke Deputy Director of Agricultural Research Department of Agriculture Peradeniya, Sri Lanka	I	1978–81	173 000
74–0016 76–0037	Thailand	Cassava Processing	Dr Nguyen Cong Thanh Associate Professor Environmental Engineering Division Asian Institute of Technology (AIT) P.O. Box 2754 Bangkok, Thailand	I II	1974–75 1977–79	16 800 57 000
74–0060	Thailand	Cassava Nutrition	Dr Sarote Khajarern Department of Animal Science Faculty of Agriculture Khon Kaen University Khon Kaen, Thailand	I	1975–78	153 300

(Table continued)

(*Table concluded.*) IDRC-Supported Root Crop Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
74–0046	Malaysia	Cassava (MARDI)	Head, Field Crops Branch Malaysian Agricultural Research and Development Institute (MARDI) Beg Berkunci No. 202 Pejabat Pos University Pertanian Malaysia Serdang, Selangor W. Malaysia	I	1975–79	320 000
72–0112	Malaysia	Microbiological Enrichment	Dean Faculty of Agriculture University of Malaya Lembah Pantai Kuala Lumpur 22–11, Malaysia	I	1973–76	99 000
73–0043 76–0060	Indonesia	Cassava	Dr Seotono, Dean Faculty of Agriculture Universitas Brawijaya Jalan Mayjen Haryono 163 Malang, Indonesia	I II	1973–76 1976–80	98 000 328 000
75–0123	Philippines	Cassava Cooperative Research (Asia)	Dr J. Cock Centro Internacional de Agricultura Tropical (CIAT) Apartado Aéreo 67–13 Cali, Colombia	I	1976–79	440 000
74–0074	Philippines	Root Crops	Dr M.R. Villanueva Acting Director National Root Crops Research Centre Visayas State College of Agriculture Baybay, Leyte 7127 Philippines	I	1976–80	302 600

*CIDA-funded and IDRC-managed project

IDRC-Supported Cropping Systems Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Latin America and Canada						
71–0005 72–0124	Colombia	Rural Development (Caqueza)	Instituto Colombiano Agropecuario Apartado Aéreo No. 7984 Bogota, Colombia	I II	1971–73 1973–77	194 000 716 000
76–0152 78–0088	Colombia	Fertilizer Development (IFDC)	Dr Donald L. McCune Managing Director International Fertilizer Development Center (IFDC) P.O. Box 2040, Muscle Shoals, Alabama 35660 U.S.A.	I II	1977–79 1979–81	347 000 390 800
78–0103	Colombia	Small Farm Modules	Ing. Martin Praeger Fundacion para la Aplicacion y la Ensenanza de las Ciencias (FUNDAEC) Apartado Aéreo 6555 Cali, Colombia	I	1979–81	49 500
77–0086	Honduras	Cropping Systems (CATIE)	Dr Hector Munoz Director of Research Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) Turrialba, Costa Rica	I	1978–80	131 100
77–0085	Nicaragua	Cropping Systems (CATIE)	Dr Jorge Soria Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) Apartado 74 Turrialba, Costa Rica	I	1978–80	132 900

(*Table continued*)

IDRC-Supported Cropping Systems Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
77–0074	St. Lucia	Cropping Systems (WINBAN)	Dr J. Edmunds Windward Islands Banana Growers' Association (WINBAN) P.O. Box 115 Castries, St. Lucia, W.I.	I	1978–81	210 000
73–0063	Canada	Plant X Plant Interaction (UBC)	Department of Plant Science University of British Columbia Vancouver, B.C. Canada V6S 2L2	I	1976–78	24 500
Africa						
77–0058	Mali	Farming Systems	Directeur Institut d'Economie Rurale Ministère du Développement Rural Bamako, Mali	I	1979–82	488 000
77–0050	Togo	Cropping Systems	M M. Amegee Directeur Ecole Supérieure d'Agronomie Université du Bénin, Rectorat B.P. 1515 Lomé, Togo	I	1978–80	53 400
78–0039	Cameroon	Plantains	Dr S.N. Lyonga Institute of Agricultural and Forestry Research Njombe, Cameroon	I	1979–82	162 000

(*Table continued*)

(Table continued)

73–0145 78–0047	Senegal	Rice Research (WARDA)	M H. Van Brandt a/s Association pour le Développement de la Riziculture en Afrique de l'Ouest (ADRAO) B.P. 29 Richard Toll, Sénégal	I II	1976–78 1978–81	410 000 679 000
72–0025 74–0087	Tanzania	Intercropping	Prof A.P. Uriyo Acting Dean Faculty of Agriculture, Forestry and Veterinary Sciences University of Dar es Salaam P.O. Box 643 Morogoro, Tanzania	I II	1972–75 1975–79	120 570 597 000
75–0122	Kenya	Crop Rotations	Dean Faculty of Agriculture University of Nairobi P.O. Box 30197 Nairobi, Kenya	I	1976–80	87 400
Middle East and North Africa						
76–0127	Syria	Crop Intensification	Ministry of Agriculture and Agrarian Reform P.O. Box 5305 Damascus, Syria	I	1977–80	242 000
77–0017	Egypt	Fertilizer Efficiency	Dr Fathy M. Amer Department of Soil and Water Science Faculty of Agriculture University of Alexandria Shatby, Alexandria Egypt	I	1977–80	191 000

(Table continued)

(Table continued)

IDRC-Supported Cropping Systems Projects

Project Number	Country	Project	Leader's Name and Address	Phase	Period	IDRC Grant (CDN $)
Asia						
74–0053 76–0087	Philippines	Cropping Systems (IRRI)	Dr H. Zandstra International Rice Research Institute (IRRI) P.O. Box 933 Manila, Philippines	I II	1974–76 1976–79	1 303 760 1 398 300
71–0107 73–0014	Philippines	Multiple Cropping (IRRI)	International Rice Research Institute (IRRI) P.O. Box 933 Manila, Philippines	I II	1972–74 1974–76	278 353 452 200
75–0086	Philippines	Multiple Cropping (UPLB)	Head Department of Agronomy University of the Philippines at Los Banos College, Laguna Philippines	I	1975–77	174 000
74–0054 78–0045	Philippines	Varietal Screening	Head Department of Agronomy University of the Philippines at Los Banos College, Laguna Philippines	I II	1974–78 1979–82	288 000 230 900

(Table continued)

(*Table concluded.*)

78–0095	Philippines	Cropping Systems Outreach (IRRI)	Head Cropping Systems Program International Rice Research Institute (IRRI) P.O. Box 933 Manila, Philippines	I	1979–82	619 000
74–0019 78–0064	Bangladesh	Cropping Systems	Dr Zahidul Haque Bangladesh Rice Research Institute (BRRI) Joydepur, Bangladesh	I II	1974–78 1979–82	418 200 397 000
75–0107 78–0050	Sri Lanka	Cropping Systems	Director of Agriculture (Research) Maha Illupallama Dryland Research Station Peradeniya, Sri Lanka	I II	1976–78 1979–82	201 000 195 000
76–0083 78–0049	Thailand	Cropping Systems	Dr Apiphan Pookpakdi Kasetsart University Rice Division Ministry of Agriculture and Cooperatives (MOAC) Bangkok 9, Thailand	I II	1976–78 1979–82	318 800 587 700
72–0006	Thailand	Multiple Cropping	Dr Banjerd Boonsue Project Director Office of Extension and Training Kasetsart University Bangkok 9, Thailand	I	1973–77	208 300
74–0157 77–0010	Indonesia	Cropping Systems	Dr Suryatna Effendi Project Leader Central Research Institute for Agriculture Bogor, Indonesia	I II	1975–77 1977–80	230 250 285 400

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